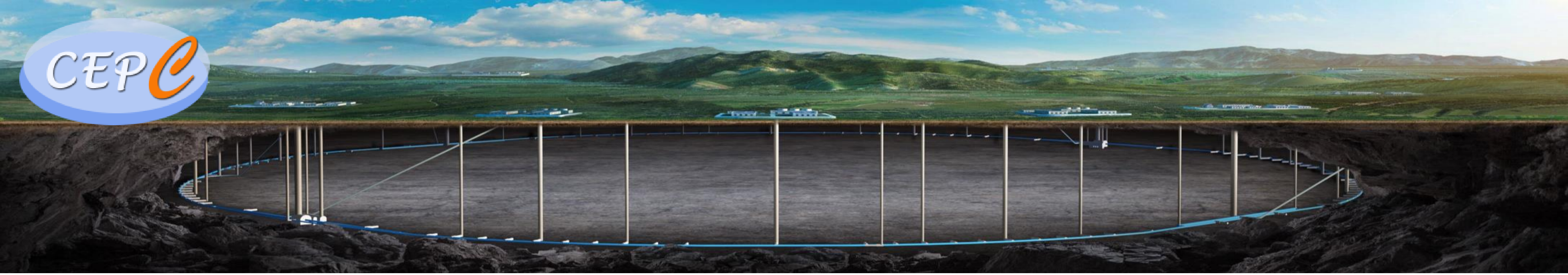
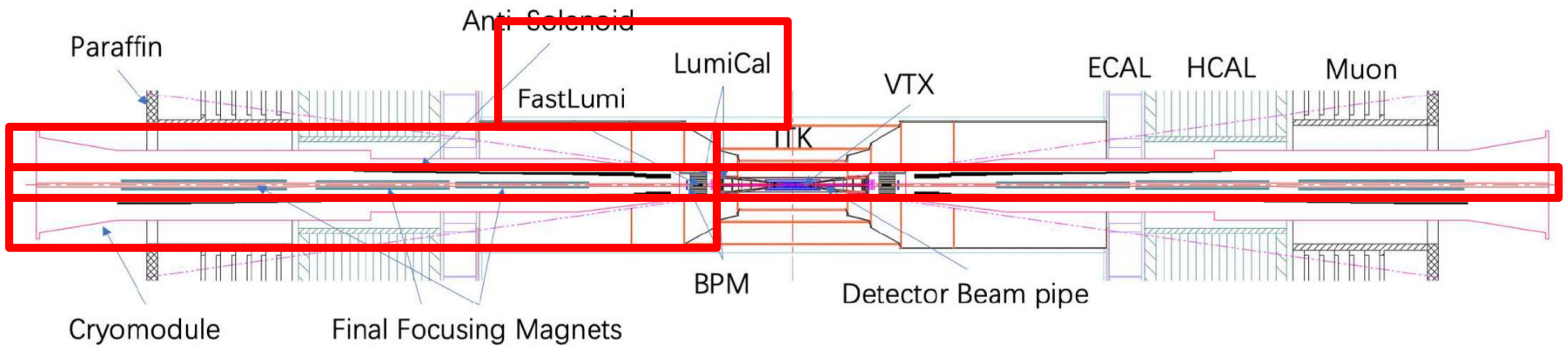


CEPC MDI EDR Status

Haoyu Shi
On behalf of CEPC MDI group

Content

Introduction - MDI layout and IR design



- **Acc. SC magnets and Cryostat**
- **Beampipe and vacuum chamber**
- **Luminosity and beam measurements**
- **Beam induced background estimation and mitigation**
- **Mechanical Integration and alignment**

- The Machine Detector Interface (MDI) of CEPC double ring scheme is about ±7m long from the IP.
- The CEPC detector superconducting solenoid with 3T magnetic field for all except of High Lumi Z.
- The accelerator components inside the detector are within a conical space with an opening angle: arccos0.99
- The e+e- beams collide at the IP with a horizontal angle of 33mrad and the final focusing length is to 1.9m.
- Lumical is between 800mm~950mm from IP, while IP BPM at 950~1050mm, currently.
- Cryostat start point at 1050mm from IP, while anti-solenoid starts at 1130mm to 6200mm from IP.

Acc SC. Magnets and Cryostat Chamber

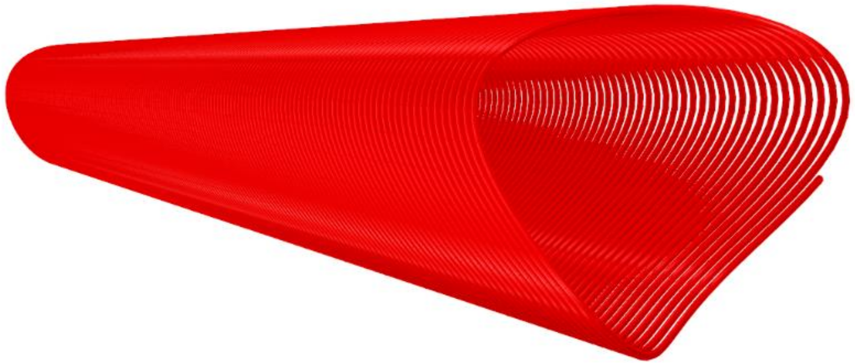
- Prototyping: The team must proceed with the construction of a prototype for the direct wind CCT final-focus quadrupole. — On-going work
- Design Optimization: The design should be revisited to potentially separate the Q1 and Q2 quadrupoles into individual cryostats to reduce the cantilevered length and allow space for a Beam Position Monitor (BPM) between them. — On-going work
- Temperature Decision: Continued studies are required to determine the optimal operating temperature (2 K vs 4.2 K) for the chosen coil technology. — 2 K is baseline.
- Quench Protection: A secure quench detection system must be developed that can trigger beam dumps and turn off detector high voltage to protect the MDI magnets. — On-going work

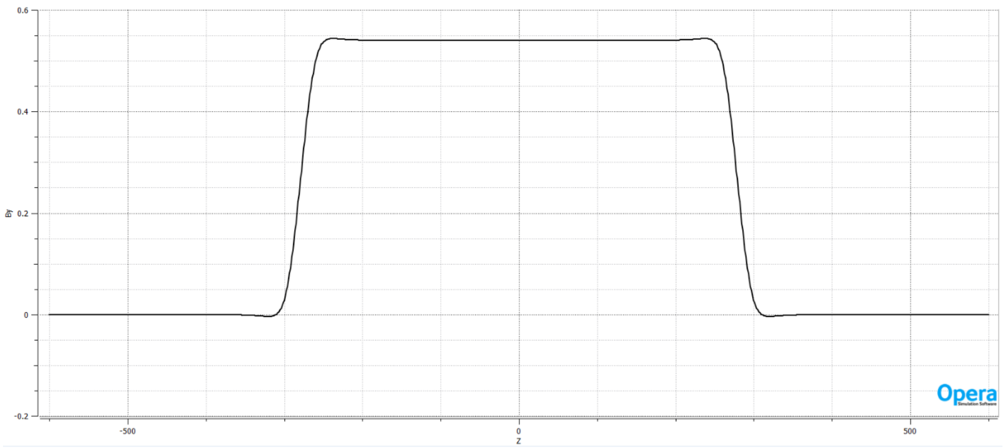
Direct winding CCT quadrupole short model status

- In EDR, the 1st step: develop a single aperture Direct winding CCT quadrupole model
  the 2nd step: double aperture CCT quadrupole model with self correction
- Main purpose: research and master key technologies of Direct winding CCT quadrupole
  Coil aperture: ∅ 40mm, Field gradient: >40 T/m @4.2K, mechanical length: 0.6m
- Due to the limitation of the funds; use existing NbTi wire in the laboratory
  Diameter 1mm or 0.6mm (not CEPC specification)

- In single aperture, a total of 6 layers Direct winding CCT coil
- Canted angle: 30 deg, pitch: 3.3 mm

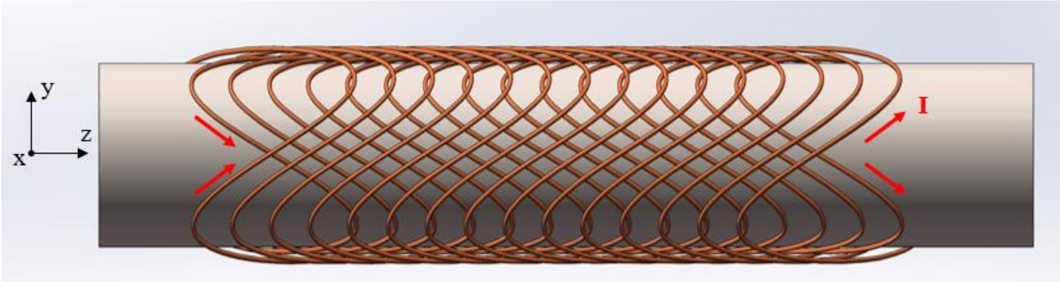
Single aperture quadrupole

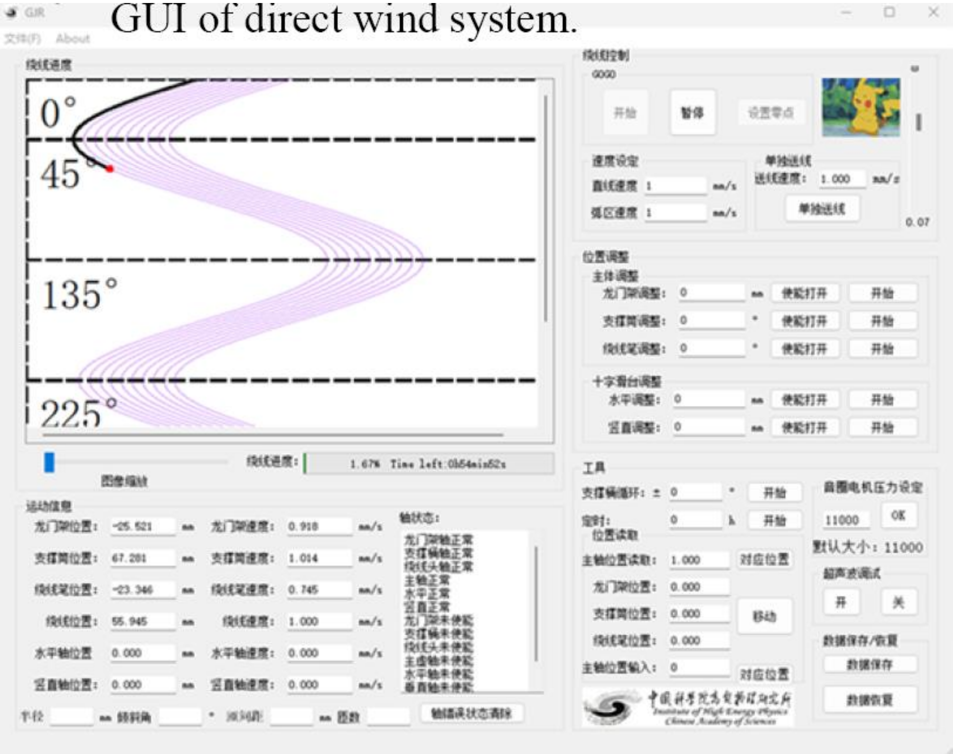




Direct winding CCT quadrupole short model status

- Direct winding experiments of CCT coil started in April, 2025
- According to the quadrupole coil design, data file of CCT coil winding path suitable for the winding machine has been generated
- Control system software of winding machine for Direct wind CCT quadrupole has been developed

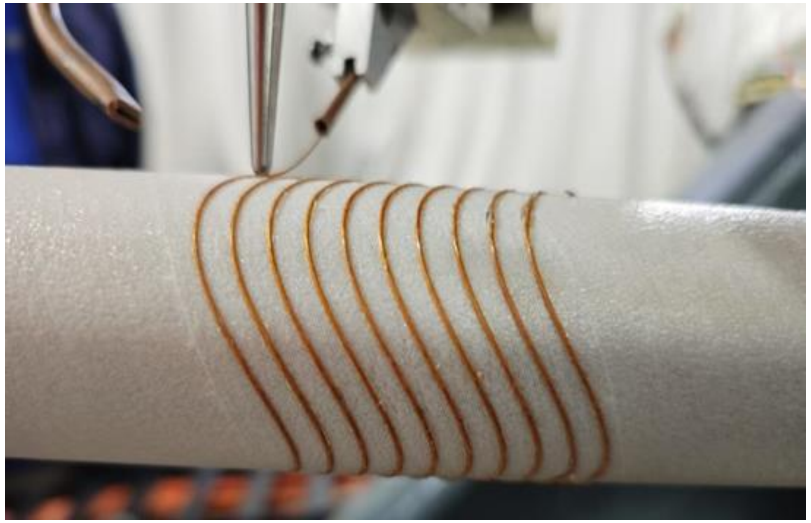




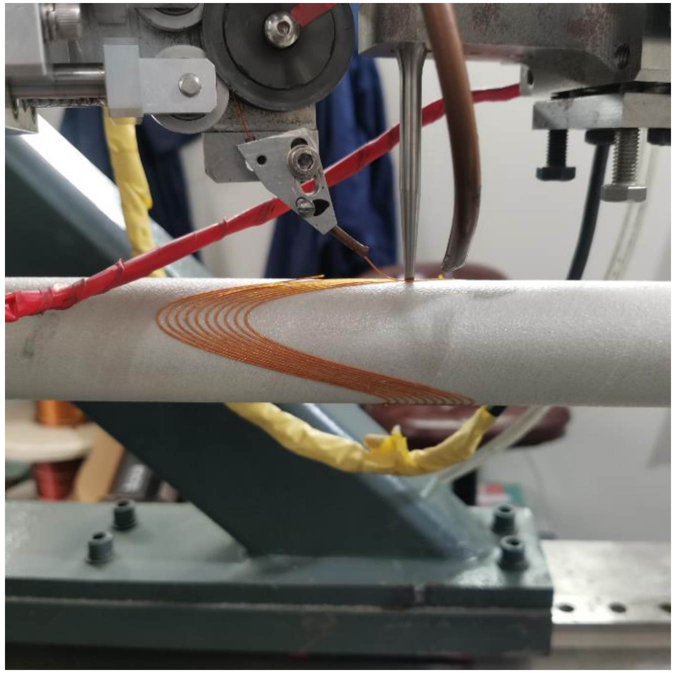
GUI of direct wind system.

Direct winding CCT quadrupole short model status

- Direct winding experiment of CCT coil has been performed
- **Use NbTi wire with 0.33mm diameter**
- Direct winding test:
  - Pure CCT quadrupole
  - CCT quadrupole coil with self correction
- The shape of the test CCT winding looks good



Pure CCT quadrupole



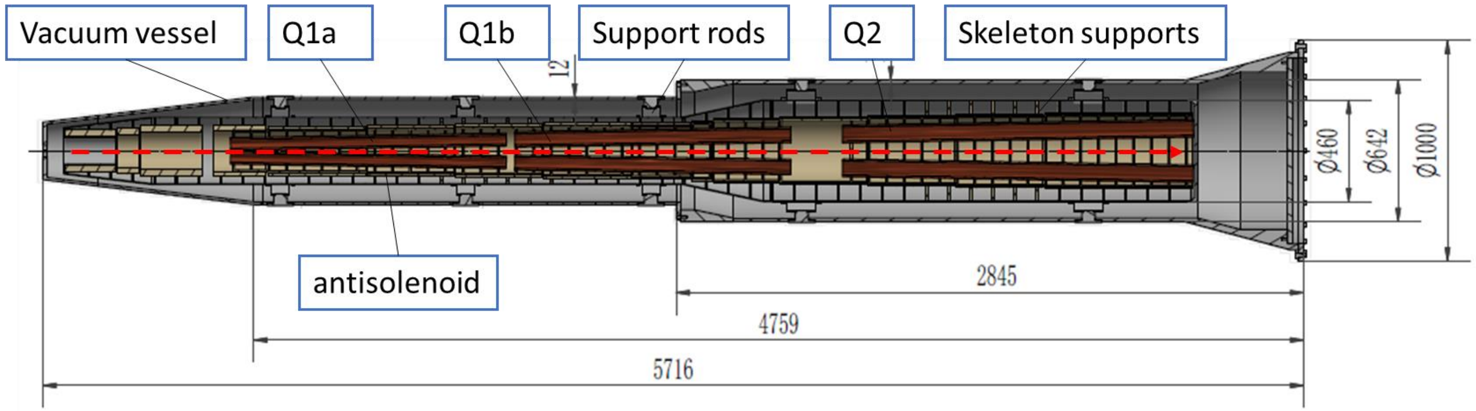
CCT quadrupole coil with self correction

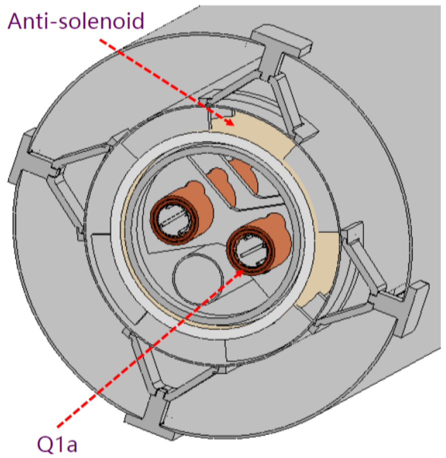
Direct winding CCT quadrupole short model status

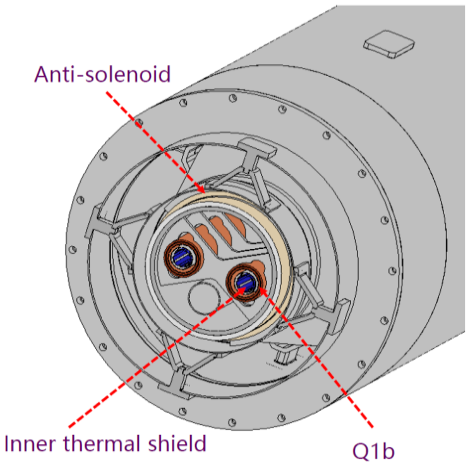
- The single aperture direct winding CCT quadrupole model will be tested at 4.2K, using cryogenic vertical test facility at IHEP
- The update of rotation coil and Hall probe measurement system located in the middle of the Dewar is in progress
- To measure the variation of field harmonics along longitudinal direction, short PCB rotating coil will be fabricated
- Vertical test will be performed in the first half of 2026

Cryostat

- The cryostat is used to provide the cryogenic environment for SC magnets, which is below 5.0 K.
- Working temperature: 2K is the baseline, 4.2K is alternative.



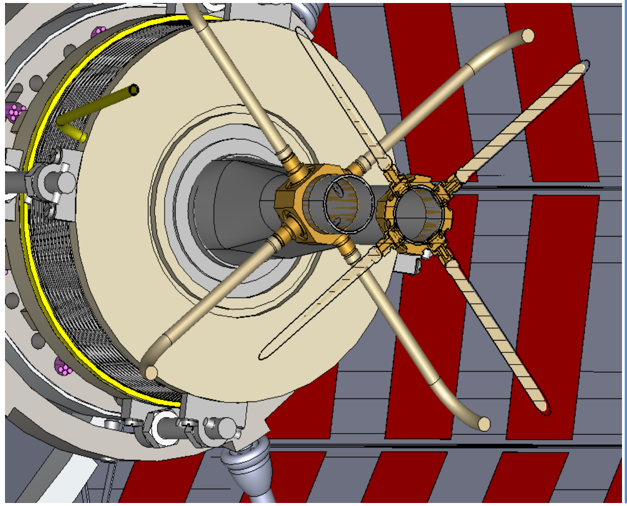


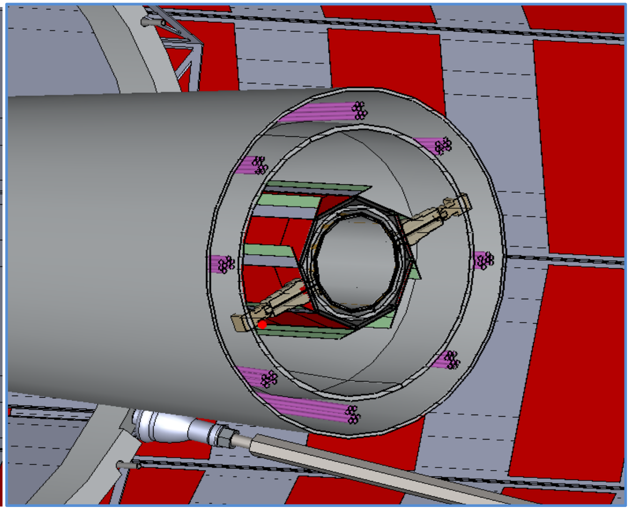


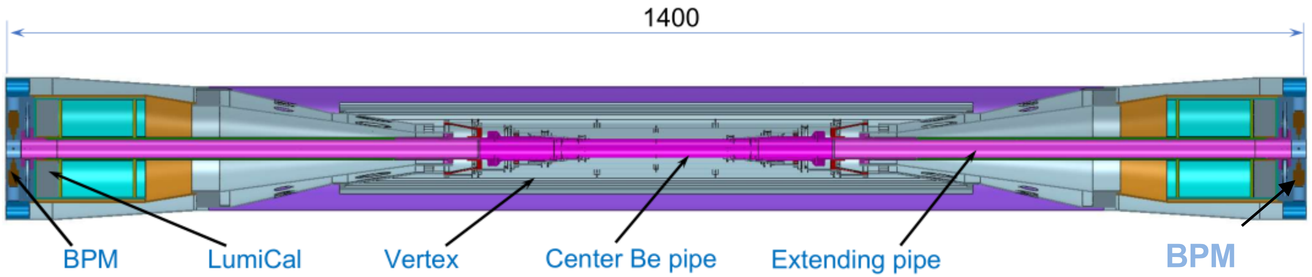
- Cryostat: a total weight of ~ 2.4 tons and a total length of ~ 5.7m.

Items	Weight (kg)	Main materials
Vacuum vessel	869	SS
Helium Vessel	510	SS
Thermal shield and pipes	43	Aluminum
SC quadrupoles	100	Copper & Aluminum
Anti-solenoids	302	Copper & Aluminum
Skeleton supports	92	Aluminum
Liquid Helium	504	Liquid Helium
Total weight	**2420**	

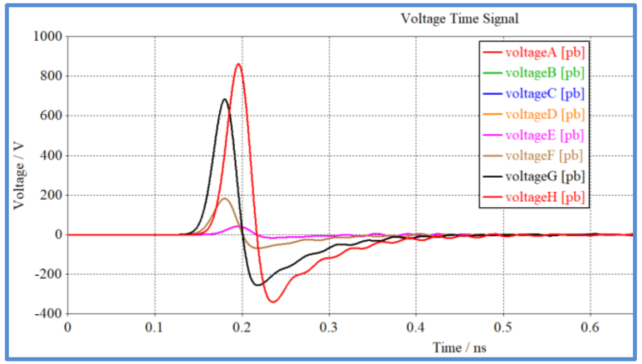
IR BPMs

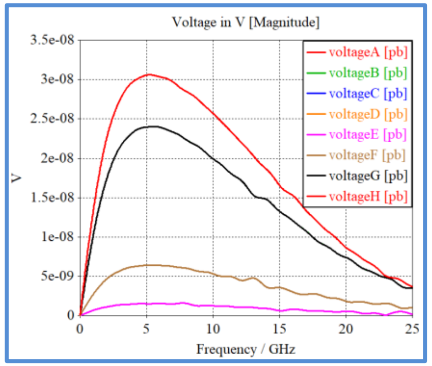






- Considering response time and calibration difficulty, two 4 button electrodes BPM in double pipe and one 2 button electrodes BPM in single pipe at each side of CEPC IR are adopted.
- 2 button electrodes BPM for measuring the arrival time.
- Utilize a pair of BPMs for vertical beam orbit feedback (fast lumi monitor for horizontal), placed at symmetric positions on each side of the IP, located at 950mm~1050mm from IP.





	Bunch charge	Bunch length	Current peak	Current average	650MHz	K_{loss}
	nC	mm	A	A	dBm	mV/pC
Higgs	20.8	4.1	607	0.208	-11.9 (-20.2)	6.76 (0.16)
Z	22.4	8.7	308	0.974	1.5 (-6.8)	0.30 (0.15)
W	21.6	4.9	527	0.216	-11.5 (-19.8)	3.4 (0.25)
ttbar	32.0	2.9	1315	0.320	-20.2 (-16.4)	15.1 (0.017)

Beam pipe and Vacuum

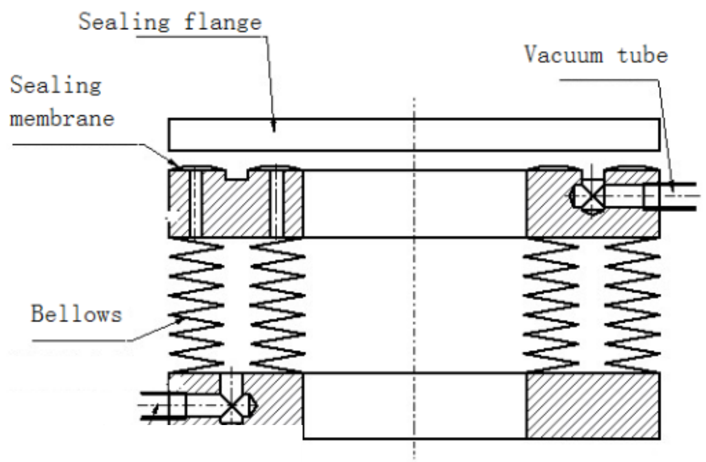
- Beryllium Chamber: A prototype of the central beryllium beam pipe is necessary to validate the feasibility of its design, particularly the challenging cooling gap and welding techniques.
- Cooling Verification: A mock-up of the beam pipe should be built to validate the performance of the cooling strategy (water vs. paraffin).
- Remote Vacuum Connection (RVC): Development of an RVC prototype should be expedited as it is considered critical equipment for MDI vacuum connections.

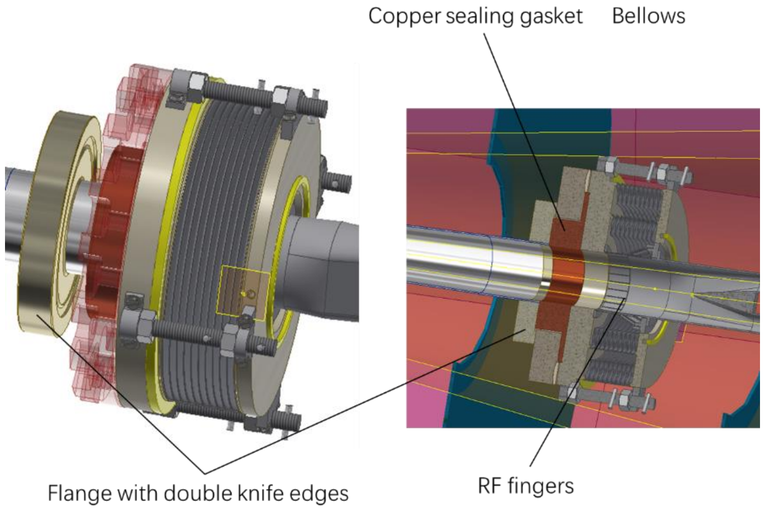
Continue study on design optimization, while seeking for funding to proceed the prototype.

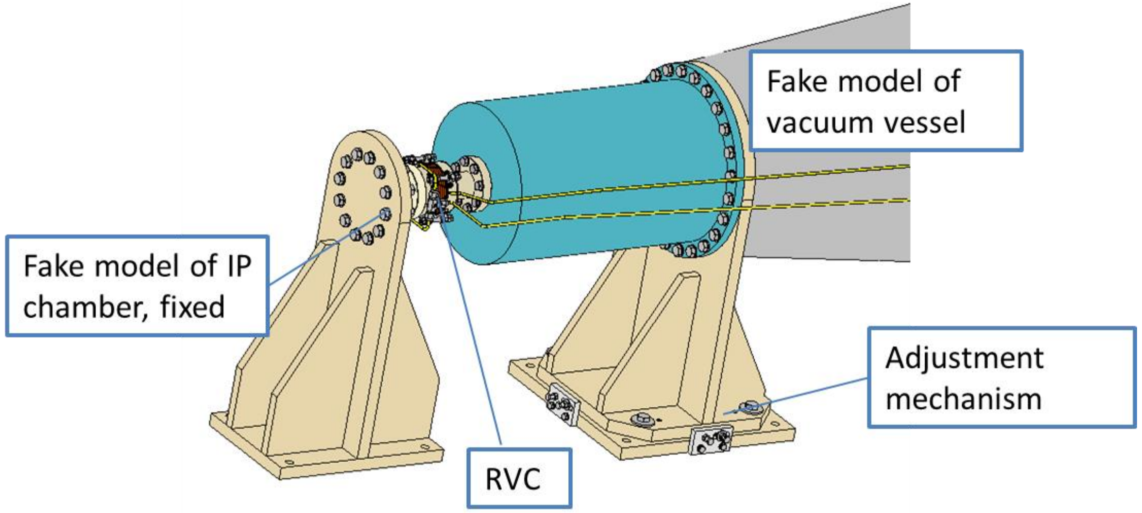
Remote Vacuum Chamber(RVC)

- RVC
  - The RVC design has been completed.
  - A prototype needs to be developed (quotation finished, and the 1st engineering drawings are prepared).
  - The influence of RVC displacement on the leakage rate will be simulated through an adjustment mechanism.

Inflatable seal







Luminosity Measurement

- The group is working on both the hardware design and the calculation of systemic errors.
- The hardware group is led by Suen Hou and Lei Zhang.
  - Currently, due to the limited space, the LumiCAL consists of two parts, one is before the flange, and one is beyond the flange. Simulation has been performed to validate such design.
  - However, some reviewers still questions about the design.
  - The group drafted a dedicated paper and submitted. Currently the paper is under review.
- The detector design and study is still on-going. More details please refer to Lei's talk this morning.

Luminosity Measurement

- Ivanka Bozovic and her team in VINCA is focused on the calculation of systemic errors.
- A lot of work has been published on this dedicated topic:

- Systematics in integrated luminosity measurement at CEPC studied so far:
  - Effects from mechanical uncertainties and MDI (240 GeV & Z-pole) *2022 JINST 17 P09014 (luminometer along s-axis), Progress of Theoretical and Experimental Physics ptae141 (2024) (luminometer along z-axis, Z-pole)*
    - maximal uncertainty of the luminometer inner radius
    - RMS of the Gaussian spread of the measured radial shower position with respect to the true impact position in the luminometer front plane
    - maximal absolute uncertainty of the longitudinal distance between left and right halves of the luminometer
    - RMS of the Gaussian distribution of mechanical fluctuations of the luminometer position with respect to the IP, caused by vibrations and thermal stress, radial and axial
    - maximal absolute angular twist of the calorimeters corresponding to different rotations of the left and right detector axis with respect to the outgoing beam
    - maximal deviation of the individual beam energy from its nominal value
    - maximal uncertainty of the average net CM energy for the Bhabha cross-section
    - maximal radial and axial IP position displacements with respect to the luminometer, caused by the finite transverse beam sizes and beam synchronization
    - maximal time shift in beam synchronization leading to the IP longitudinal displacement
  - Physics processes as background to the Bhabha count *2022 JINST 17 P09014*
  - Impact of EMD *arXiv: 2511.00687 [hep-ex], submitted to the Progress of Theoretical and Experimental Physics (2025)*

- Data-driven correction of uncertainty of the crossing angle *arXiv: 2511.00687 [hep-ex], submitted to the Progress of Theoretical and Experimental Physics (2025)*
- Measurement of the beam energy spread (BES) *2022 JINST 17 P09014*
- Impact of BES uncertainty on precision EW observables *2022 JINST 17 P09014*

Luminosity Measurement

- The critical issues of the study has been identified

  - Systematics in integrated luminosity measurement at CEPC, critical issues:
    - Effects from mechanical uncertainties and MDI (240 GeV & Z-pole)
      - maximal uncertainty of the luminometer inner radius ➡ ~ 1 μm
      - RMS of the Gaussian spread of the measured radial shower position with respect to the true impact position in the luminometer front plane ✔
      - maximal absolute uncertainty of the longitudinal distance between left and right halves of the luminometer ✔
      - RMS of the Gaussian distribution of mechanical fluctuations of the luminometer position with respect to the IP, caused by vibrations and thermal stress, radial and axial ✔
      - maximal absolute angular twist of the calorimeters corresponding to different rotations of the left and right detector axis with respect to the outgoing beam ✔
      - maximal deviation of the individual beam energy from its nominal value ➡ 7 MeV (is this critical?)
      - maximal uncertainty of the average net CM energy for the Bhabha cross-section ➡ relative uncertainty has to be the same as $\Delta L/L$
      - maximal radial and axial IP position displacements with respect to the luminometer, caused by the finite transverse beam sizes and beam synchronization ✔
      - maximal time shift in beam synchronization leading to the IP longitudinal displacement ✔
    - Physics processes as background to the Bhabha count ✔
    - Impact of EMD ➡ of order of ~ $4{\cdot}10^{-3}$ at Z-pole; Requires correction from simulation

  - Data-driven correction of uncertainty of the crossing angle ✔
  - Measurement of the beam energy spread (BES) ➡ 9 MeV @Z-pole implies 10^{-3} effect for a detector on the s-axis; How about z-axis?
  - Impact of BES uncertainty on precision EW observables ✔

Luminosity Measurement

- And the questions, together with the next plan.

1. Systematics in integrated luminosity measurement at CEPC, additional issues & work to do:
    - Effects from mechanical uncertainties and MDI (240 GeV & Z-pole): the study is based on BHLUMI counts in the luminometer fiducial volume. What is the impact of realistic Bhabha reconstruction (in the presence of backgrounds) on the obtained results?

2. Impact of EMD requires correction from simulation: develop a correction method based on experimental data *(ongoing)*

3. What is the impact of 20 mrad inner aperture acceptance on 1 and 2? (i.e. Bhabha will be more affected by the fields of the incoming bunches, but, also, some correction methods for EMD could work better with a larger statistics in the detector) *(planned)*

4. Do we fully understand the existing simulation of beam-beam interactions (Guinea-Pig ++), in terms of control and reproducibility of the existing results?
    - The answer seems to be NO ➡ *A dedicated group has been formed (currently VINCA, Belgrade and IHEP Beijing) for a dedicated study*
    - It is worth nothing that this issue affects all processes (not only Bhabha) including background to be tracked in the fields of incoming bunces with potential implications on detectors' occupancies and shielding

Beam induced backgrounds

- Solenoid Compensation: The MDI design must be finalized by including the solenoid compensation scheme, specifically verifying coupling compensation at the Z-pole with a 3 T detector solenoid.
- Simulations: Detailed simulations must include synchrotron radiation (SR) produced by the injected beam and account for orbit misalignments to ensure the design of SR masks is robust.
- Collimation: Further studies are needed to refine the collimation scheme to protect critical accelerator components and control backgrounds. This includes evaluating the impact of collimator apertures on impedance budgets and beam lifetimes.

Baseline is local compensating scheme.

The validation of the tools and codes is ongoing.
The study on misalignment of the beam pipe(also the SR masks) is ongoing.

Starting from the check of the modification due to injection background study.

Beam Background Sources and Simulation Steps

- We will mainly focus on estimation of the BIB level at 50 MW Higgs mode.
  - 50 MW Higgs -> 12.1 MW Z -> W -> 50 MW Z -> ttbar

- The study of the BIB is still based on TDR Lattice and Reference Detector.

Table 3.3: Design parameters of the CEPC accelerator used in beam-induced background study. The parameters of 50 MW Higgs mode and high luminosity Z mode (High-Lumi-Z) are taken from Ref. [1] and Ref. [6], while the parameters of 12.1 MW low luminosity Z mode (Low-Lumi-Z) taken from Ref. [7].

Parameters	Higgs	Low-Lumi-Z	High-Lumi-Z
Number of IPs	2		
Half crossing angle at IP (mrad)	16.5		
Solenoid Magnet[T]	3		2
SR power per beam [MW]	50	12.1	50
Energy [GeV]	120	45.5	45.5
Bunch number	446	3978	13104
Bunch spacing [ns]	277.0	69.2	23.1
Train gap [%]	63	17	9
Bunch population [10^{11}]	1.3	1.7	2.1
Beta functions at IP β_x^*/β_y^* (m/mm)	0.3/1	0.2/1.0	0.13/0.9
Emittance x/y (nm/pm)	0.64/1.3	0.27/5.1	0.27/1.4
Beam size at IP x/y [um/nm]	14/36	6/72	6/35
Bunch length (total) [mm]	4.1	8.8	10.6
Energy spread (total) [%]	0.17	0.13	0.13
Energy acceptance (DA) [%]	1.6	1.0	1.0
Luminosity per IP [$\times 10^{34} cm^{-2} s^{-1}$]	8.3	26	192

- Single Beam
  - Touschek Scattering
  - Beam Gas Scattering(Elastic/inelastic)
  - Beam Thermal Photon Scattering
  - Synchrotron Radiation
- Luminosity Related
  - Beamstrahlung/Pair Production
  - Radiative Bhabha Scattering
- Injection
- SuperKEKB like sudden beam loss
- Failure Case(injection/extraction/Power Loss…)

} Done for Ideal beam with beam-beam
The misalignment and beam orbit change is ongoing with acc. colleagues, since the final strategy and beam orbit has not been fixed yet.

From Last Dipole+FFS+Uniform Solenoid, VTX only

} Pair Production with Gienea-Pig++

Just started. The BG can be shielded by collimators.

} Not studied yet. Power loss studied by PMP group.

Pair Production

- The dominant one
- Rely on Guinea-Pig++, which seems to have some issues.
- In last several months, we are trying to study more starting from the Guinea-Pig++ paper published in 2005.
  - Seems to be failed. We can not re-present the published results.
- A dedicated group formed, led by Ivanka Bozovic. Joint effort of VINCA and IHEP.
  - Bi-weekly Meeting since Jan 16th, 2025.
- FCC-ee also work on these issues and progress quickly.
  - A MIT Team.

SR & Single Beam

- We implemented the IR lattice and the magnetic field into the new version of BDSIM.
- This year, we plan to validate the tools and codes using BEPCII and Upgrades.
  - Using BDSIM to calculate the SR BG for BIIU. Thinking about experiments.
    - Back-to-back cross-check
  - Using SAD and home-built generators to simulate BEPCII/BESIII, understands more.
    - A dedicated BESIII MDC BG Group formed. Weekly Meeting.
  - Using the same code to simulate BII(U) BG. Cross-check also involved.

Injection Beam Background Study -- Preliminary

- We simulate the injection beam in injection point with some cases:
  - The ideal beam using the emittance and other profile of injection beam
  - The beam with normal gaussian distribution(energy, position, direction, etc…)
  - The beam with certain energy deviation.
  - The beam with certain position deviation.
  - The beam with certain direction deviation.
- The study is preliminary and still on-going, but the loss particles of the injection BG can be shielded outside of the interaction region by collimators.

Shielding and Mitigation

- Shielding is designed to prevent beam background from damaging detector.
- Shielding has been implemented at both ends of the yoke using the 10 cm of paraffin, and also 10mm W outside of the LumiCal-LYSO. The shell of cryo-module also used as shielding. The optimization of the shielding is on-going but will be proceed after the validation and the study on generator.
- The geometry in simulation tool of the experimental hall is under-developing.
- Finding the hotspots and trying to implement local shielding instead of the uniform shielding.
  - Collaborate with CEPC TPC/LCTPC Team and Daniel Jeans(FCC-ee , ILD, KEK).
- The collimators is modified in the injection background study; the checking of the effectiveness of the modified version is on-going.
- Continue optimize the collimators, taken the impendence into account. Using some ML techniques to optimize.

Mechanical Integration and Alignment

- Vibration Studies: Measurements of vibrations at the proposed site and their impact on the beam offset at the interaction point are required.

  Just started.

- Mock-up Assembly: A mock-up of the MDI that simulates the weight distribution of components is suggested to validate modal analysis and mechanical stability.

  Continue study on design optimization, while seeking for funding to proceed.

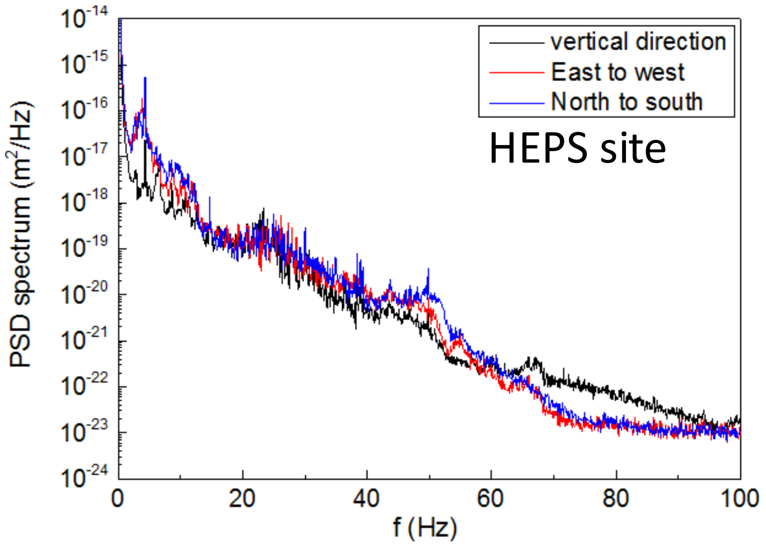
- Alignment Strategy: The alignment strategy for the MDI area needs to be finalized, and specific solutions (such as monitoring systems) must be qualified.

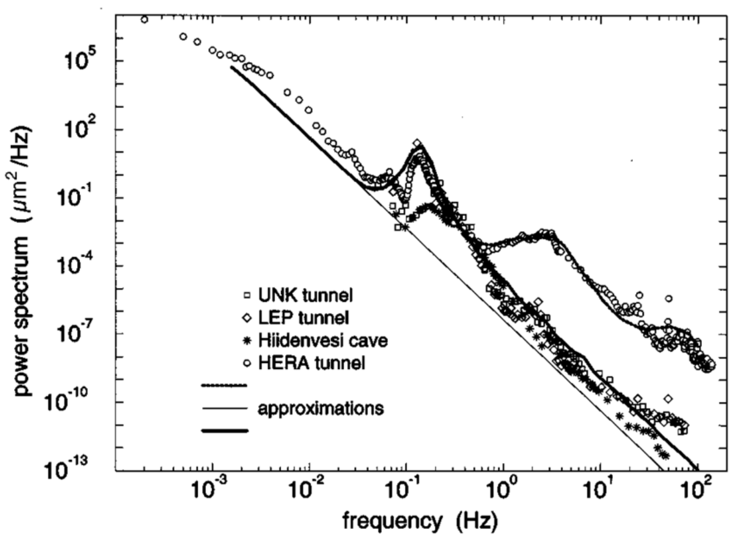
  On going work.

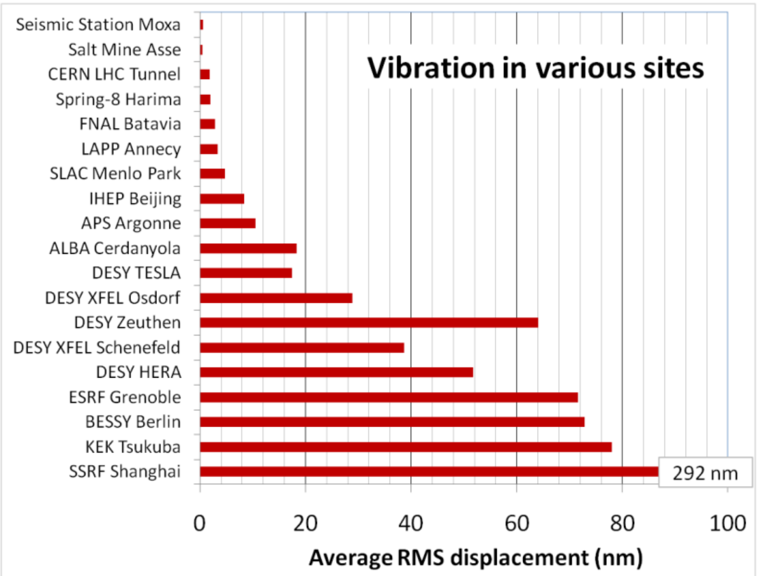
Vibration test scheme

- Mechanical dynamic stability (vibration)
  - Ground vibration:
  - Magnet-support assembly: natural frequency? Amplification factor?
  - Damping devices: damping material? active vibration technology?
- Enhancing the natural frequency is an effective method to decrease vibration.

	Ground motion requirements, RMS, 1-100 Hz displacement integral
MDI	≤4 nm
Arc and straight section, and RF section in Collider	≤24 nm
Linac	≤50 nm







Vibration test scheme

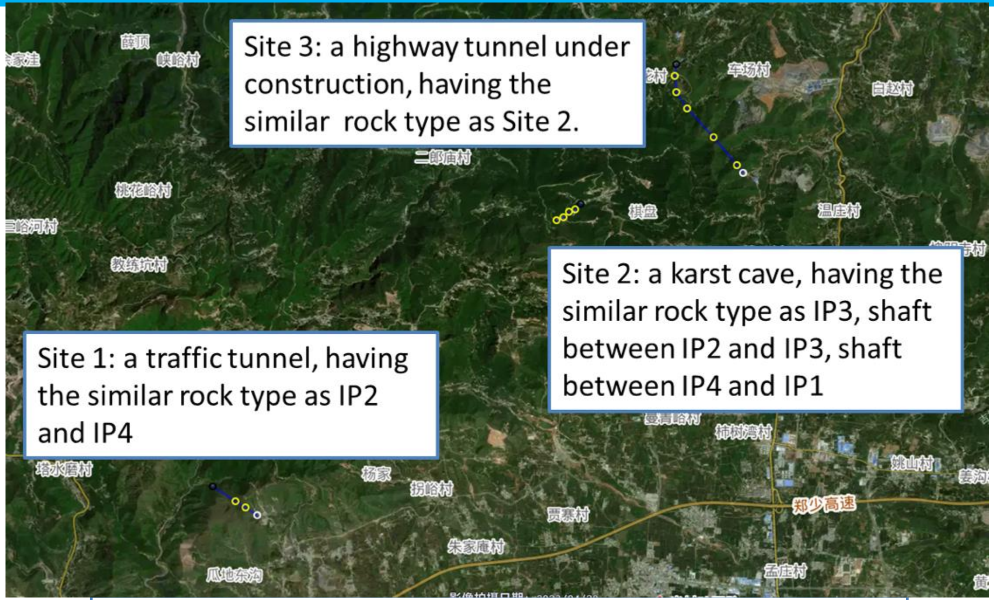
This scheme is mainly focused on the ARC sections, but the methods are also works for MDI. The dedicated MDI vibration test is on going.

- Test scheme

Test contents		Site requirements
Ground motion test	Amplitude of ground vibration	Close to a real tunnel site
	Wave velocity and vertical attenuation.	
Modal test on magnet & support assembly	Collider magnet & support	Good vibration performance, to validate the rationality of the design
	Booster magnet & support	

  - The test sites has been identified.
  - The vibration sensors have been tested and identified.


Sensor testing at PAPS and HEPS



Ground motion test sites


Modal test sites, at JUNO

Summary and Outlook

- MDI is one of the most critical part of the CEPC. It contains a lot of components and sub-systems. Each of them are in different phase, thus will have different goals in EDR, including this year.
- Our current goal is keep optimizing the design, finishing the test and prototype on key technologies, while seeking for funds to support other prototypes.
  - For the design optimization,
    - We are studying the number of the cryostat and the scheme of compensating.
    - We are studying the impact of Beamstrahlung and other issues on luminosity measurement.
    - We are studying the impact on BIB due to the misalignments and optimizing the mitigation methods.
    - We are optimizing the MDI alignment strategy including the influence of RVC displacement on the leakage rate.
  - For the experiment and prototype,
    - The prototype of the direct winding CCT coils is ongoing.
    - We are performing the vibration test.
    - We are validating the tools and codes used in BIB study using existing machines like BEPCII/HEPS/etc.
- And try to collaborate with FCC-ee people and others.

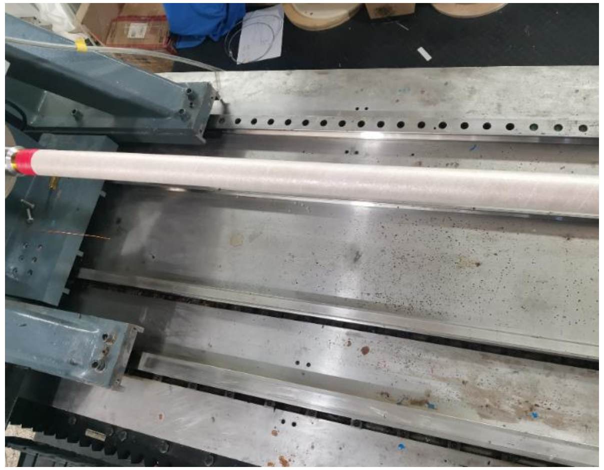
Thanks for your attention

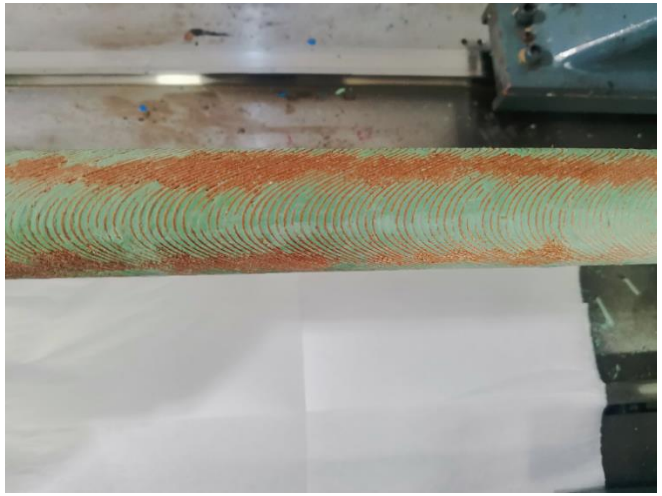
Backup

Direct winding CCT quadrupole short model status

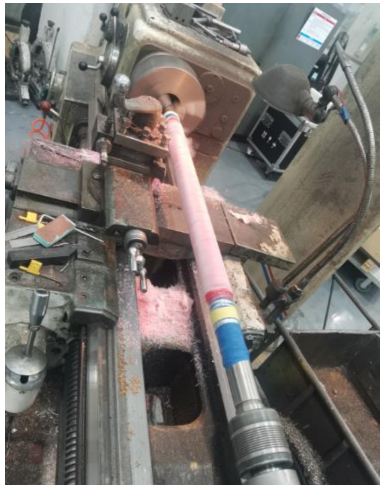
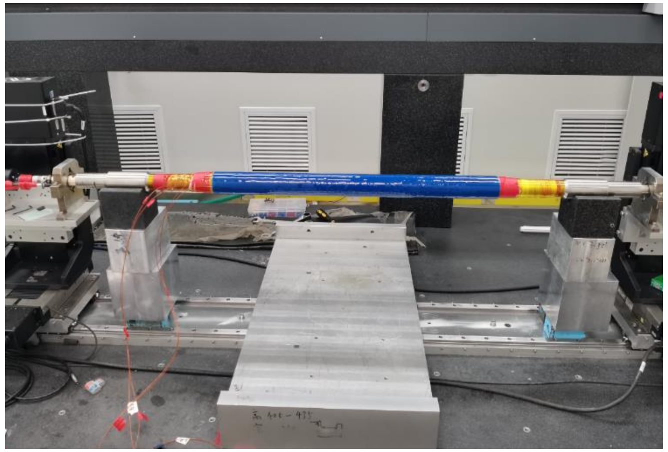
- Main fabrication process of one double-layer CCT using direct winding technology:

Wrap substrate ➡ coil winding ➡ apply epoxy ➡ apply pre-stress ➡ surface machining ➡ room temperature magnetic field measurement



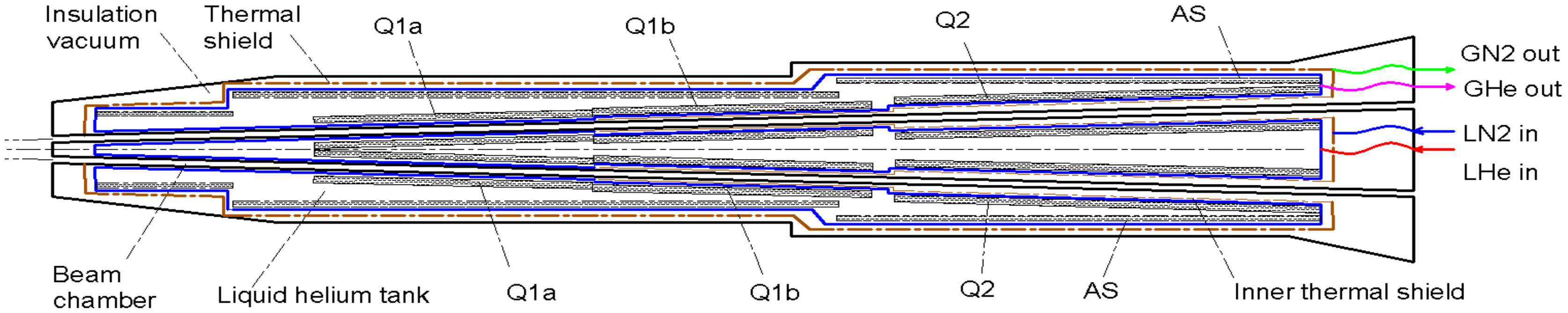


4 layers CCT coils have been wound

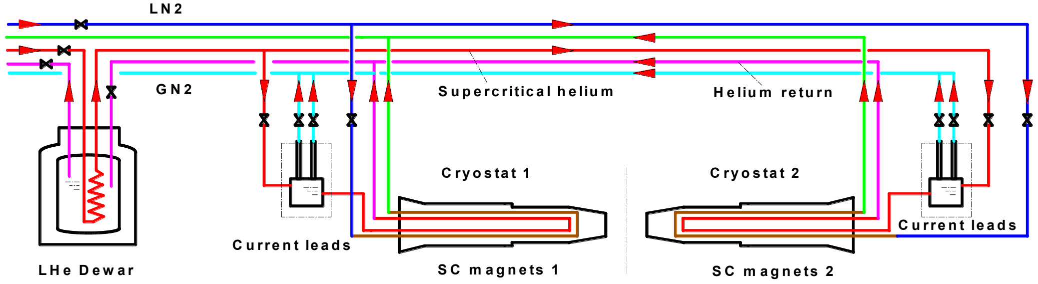
Cryogenic scheme of the cryostat

Cryostat scheme

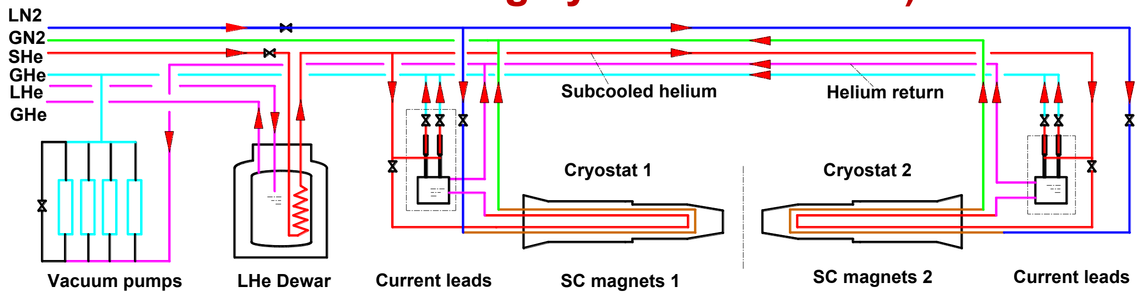


- Superconducting magnets are immersed in the helium tank for the low temperature.
- One thermal shield is set for the heat interruption from the ambient temperature.
- The shield is extended between the helium tank and the beam chamber.
- The cold mass can be cooled by supercritical, subcooled, or superfluid liquid helium, and the shield is by liquid nitrogen.

4 K cooling system(alternative)



2 K cooling system（baseline)



Thermal analyses – Synchrotron radiation

- SR heat load without Masks

Region	ttbar		Higgs		Z	
	SR heat load	SR average power density	SR heat load	SR average power density	SR heat load	SR average power density
0~780mm	0	0	0	0	0	0
780mm~805mm	11.88W	132W/cm^2	23.04W	256W/cm^2	11.8W	131.1W/cm^2
805mm~855mm	27.53W	152.9W/cm^2	53.39W	296.6W/cm^2	27.4W	152.2W/cm^2
855mm~1.9m(Q1a entrance）	2.22W	0.59W/cm^2	4.32W	1.15W/cm^2	2.2W	0.59W/cm^2
Q1a（1900-3110）1210	1.69W	0.38Wcm^2	3.28W	0.75W/cm^2	1.68W	0.38W/cm^2
Q1a~Q1b（3110-3190）	11.8W	40.97W/cm^2	22.92W	79.58W/cm^2	11.75W	40.8W/cm^2
Q1b（3190-4400）	2.04W	0.47W/cm^2	3.96W	0.91W/cm^2	2.03W	0.47W/cm^2
Q1b~Q2(4400-4700)	36.6W	33.9W/cm^2	71.04W	65.8W/cm^2	36.4W	33.7W/cm^2
Q2(4700-6200)	3.74W	0.69W/cm^2	7.26W	1.34W/cm^2	3.72W	0.69W/cm^2

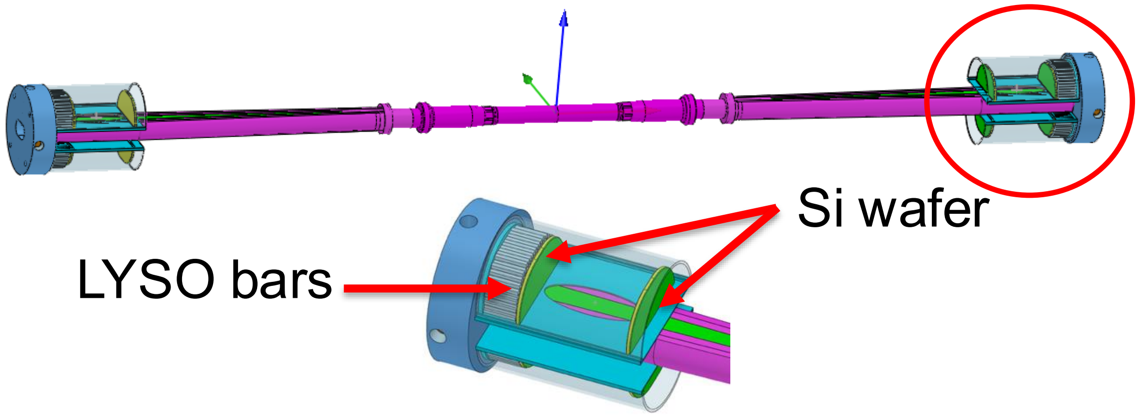
Thermal analyses – HOM & Resistance wall

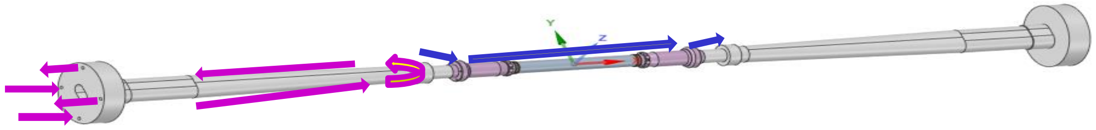
- HOM & Resistance wall

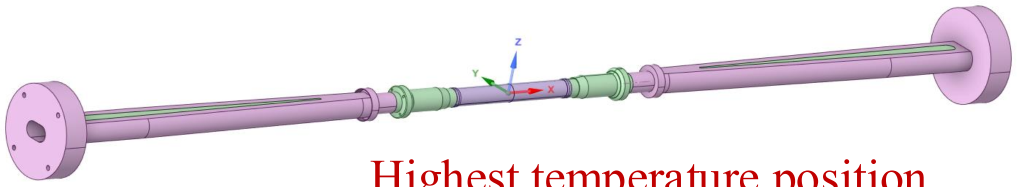
Position	Position Start-end（mm）	material	Length (mm)	Higgs (w)&(w/cm^2)	W (w)&(w/cm^2)	Z (w)&(w/cm^2)	ttbar (w)&(w/cm^2)
Be pipe (w&w/cm^2)	0-110	Be	110	1.46 & 0.021	7.230 & 0.105	**71.558 & 1.035**	0.401 & 0.005
Be pipe transition(w&w/cm^2)	110-180	Al	70	0.45 & 0.01	2.173 & 0.049	**21.574 & 0.491**	0.127 & 0.007
Transition pipe (w&w/cm^2)	180-655	Al	475	6.99 & 0.017	34.48 & 0.085	**341.562 & 0.83**	1.958 & 0.005
Transition （w&w/cm^2）	655-700	Al	45	0.62 & 0.015	2.95 & 0.071	**29.28 & 0.701**	0.172 & 0.004
RVC bellow（w&w/cm^2）	700-780	Cu	80	0.52 & 0.007	2.532 & 0.034	**25.002 & 0.337**	0.14 & 0.002
Transition on Y-crotch(w&w/cm^2)	780-805	Cu	25	0.16 & 0.007	0.785 & 0.032	**7.822 & 0.316**	0.05 & 0.002
Y- crotch (w&w/cm^2)	805-855	Cu	50	0.33 & 0.005	1.572 & 0.024	**15.626 & 0.241**	0.091 & 0.002
Quadrupole pipe(w&w/cm^2)	855-1100	Cu	245	1.58 & 0.005	7.735 & 0.024	**75.594& 0.24**	0.434 & 0.002
Total	0-1100	-	1100	12.11 &0.011	59.457 &0.056	**588.018 & 0.56**	3.373 & 0.003

The central beam pipe design

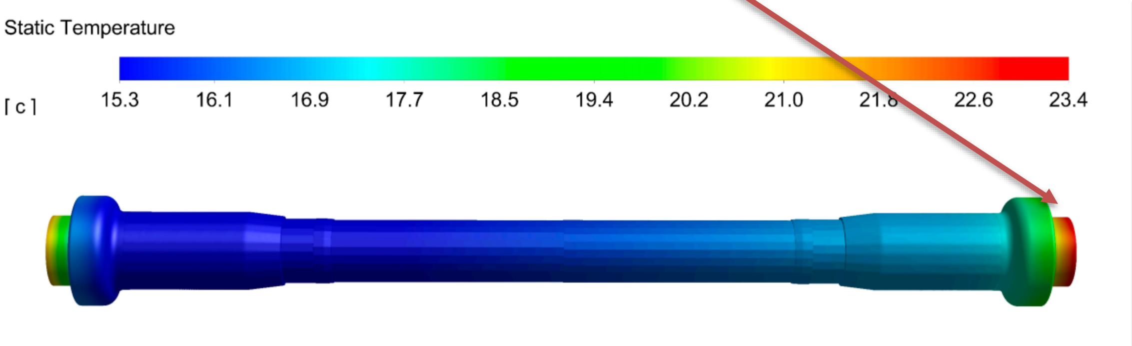
- Central Be pipe segment: 380mm, the inner diameter: 20mm
- The inner Be layer: 0.2mm
- Outer Be layer: 0.15mm (to improve the accuracy of vertex)
- the cooling gap: 0.3 mm, Paraffin
  0.2 mm, Water







Highest temperature position

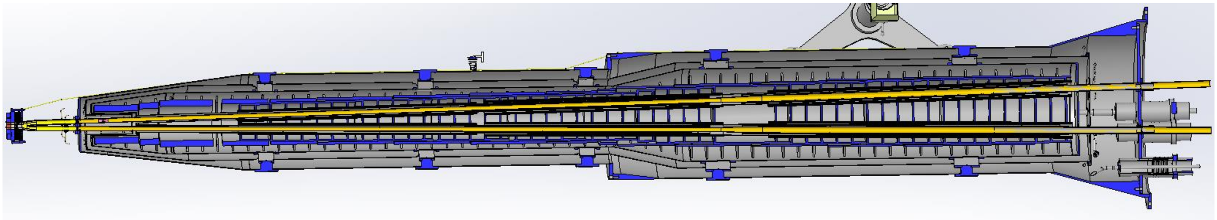


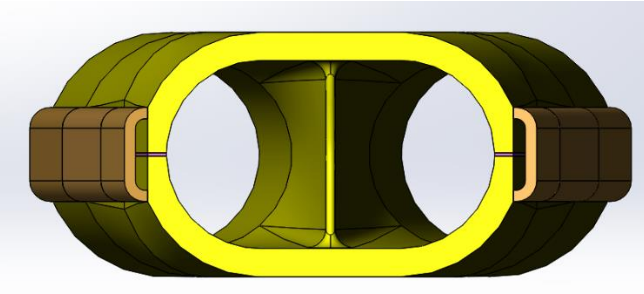
Highest temperature: 23.4°C

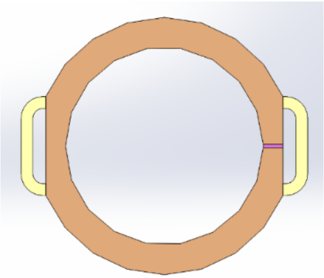
- Water is the basic design and Paraffin is alternative choice.
  - Performing more simulation to study the difference between this two.
- Dynamic temperature/pressure could meet the requirements.

IR vacuum chamber

- The total length of MDI vacuum system is about 14m, mainly composed of vacuum chamber, bellows, beryllium pipe, cooling system, support system, etc.
- Due to limited space at MDI region, not possible to install a vacuum pump, and NEG coating is chosen.

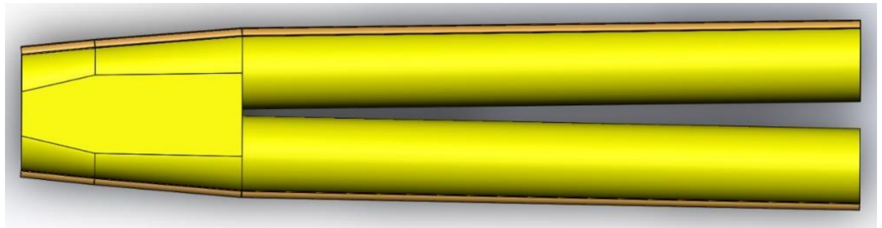






From IP(mm)	Shape	Inner diameter(mm)	Material	Marker
0-110	Circular	20	Be	
110-180	Circular	20	Al	
180-655	Race-track	20~35	Al	Taper: 1:70
655-700	Race-track	35	Al	
700-780	Race-track	35	Cu	
780-805	Race-track	35~39	Cu	
805-855	Race-track	39~20 double pipe	Cu	

Q1a-Q1b-Q2：20mm-23mm-32mm
Cone+circular beam pipe structure with gradually increasing aperture

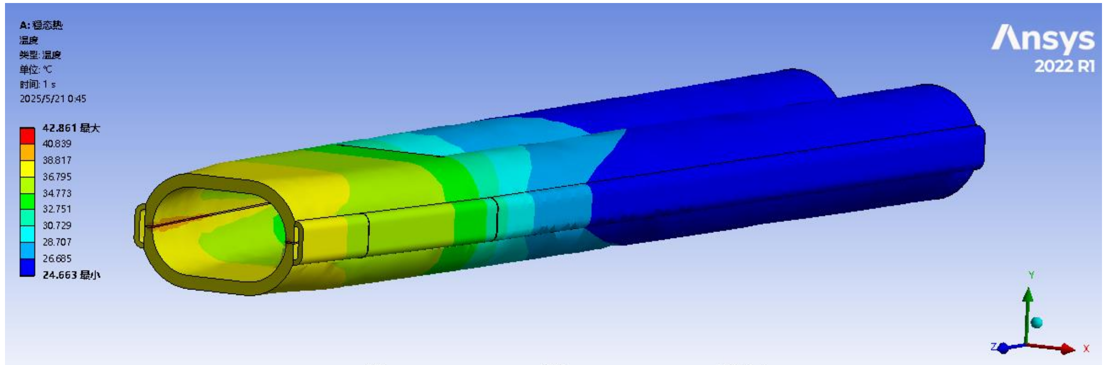


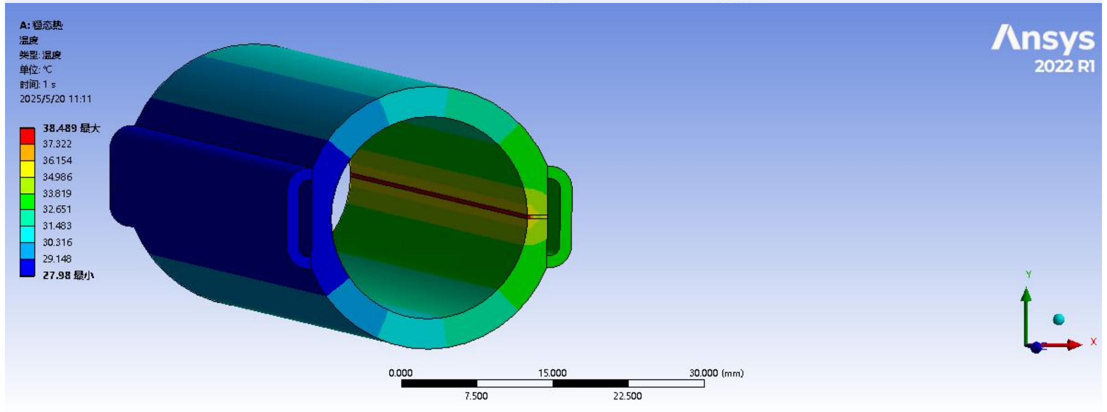
mode	E (Gev)	Beam lifetime (hours)	Vacuum pressure (Torr)
Higgs	120	10	2×10^{-9}
W	80	5	1.5×10^{-9}
Z	45.5	3	8×10^{-10}
tt	180	15	1×10^{-8}

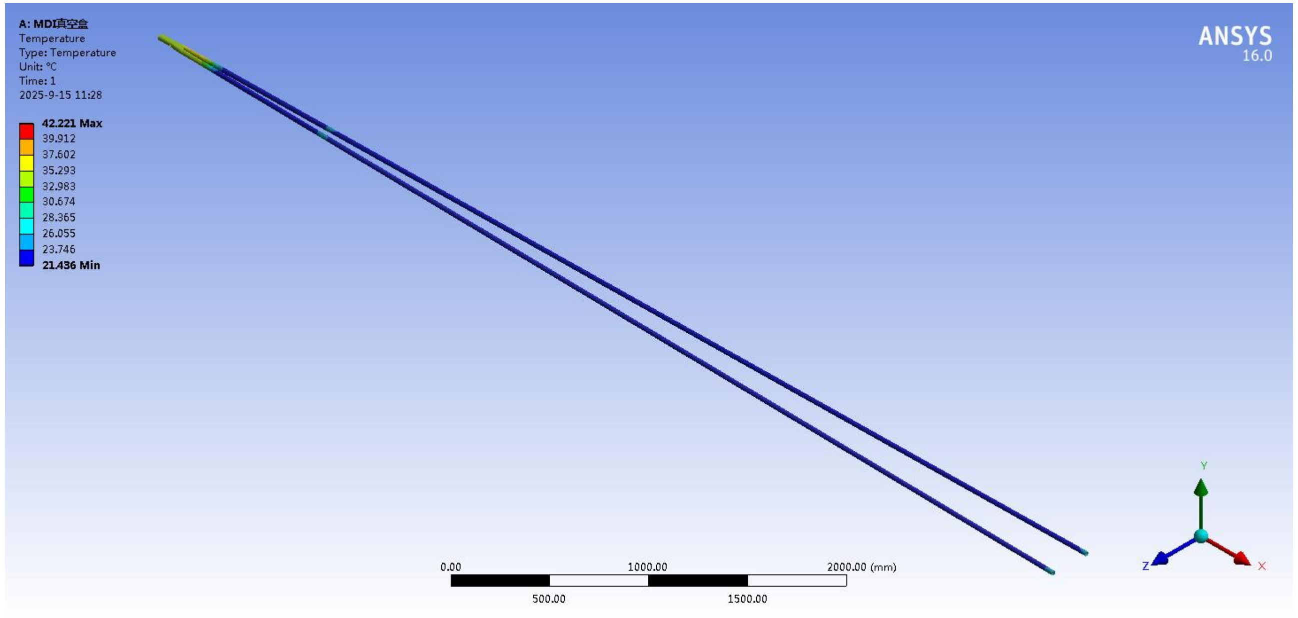
- The beam pipe is made of chromium zirconium copper material (Cr-Zr-Cu) C18150.
- Water channels welded on the outside for cooling the SR heat load.
- Cr-Zr-Cu has low photon desorption capacity, high thermal conductivity, and can effectively prevent photons from penetrating the vacuum chamber and damaging magnets and other hardware.
- Bellows was installed at the connection of vacuum chamber which can compensate for the thermal expansion, contraction, and offset of the vacuum chamber, and provide continuous RF shielding between two connected vacuum chambers to reduce the impedance.

Thermal analysis of IR beam pipe

- Thermal analyses of beam pipe at cryostat @Higgs, 50MW





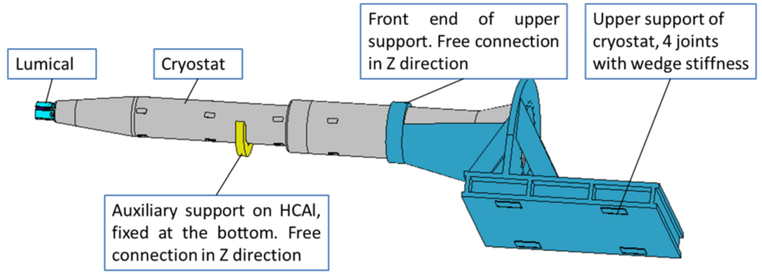


- Two masks at 1.9m and 7.2m respectively, and the power density is highest at masks.
- The power density of SR at Mask1 is ~ 2.966 W/mm^2, and at Mask2 is ~3.2 W/mm^2.
- The power density at the crotch part is 2.97 W/mm^2, while at other positions is less than 0.8 W/mm^2 ;
- The highest temperature at crotch part is 42.86 ℃, and at Masks is 38.5 ℃. The other part is the cooling water temperature.

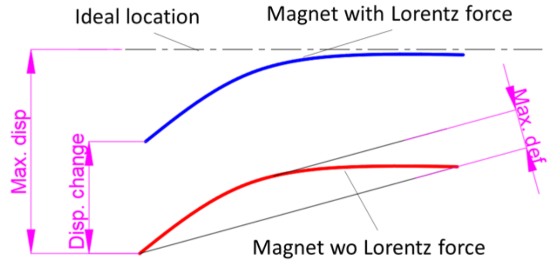
SC magnet support system

- Mechanics and vibration analyses
  - The cryostat and its supports at MDI have been optimized.
  - The first natural frequency has been enhanced 3 times, from 17.7Hz to 49.2 Hz.
  - The Max. def. and disp. Change is smaller than 40 um, which means it has little effect on alignment, and no re-alignment is needed after having Lorentz force.

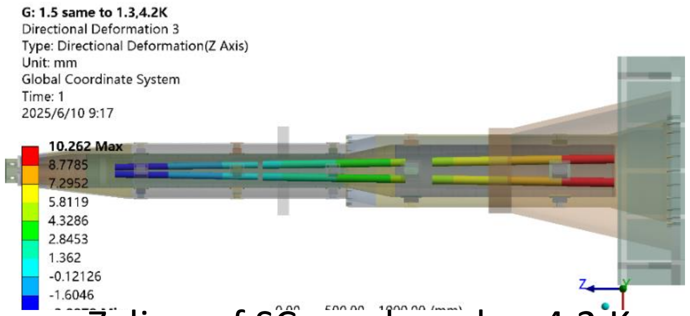
	Related requirements	Response now*
Position accuracy (X/Y) of SC quadrupoles ≤100μm	Adjusting resolution≤5μm Adjusting accuracy≤30μm	≤5μm ≤30μm from HEPS experience
	Max. def. and disp. change, ＜ 50μm	FEA, ＜40μm
Small vibration, 1-100Hz RMS ≤4nm	High natural frequency	FEA, ~50Hz and 1 (same level to HEPS, and arc section of CEPC)
	Low amplification factor	



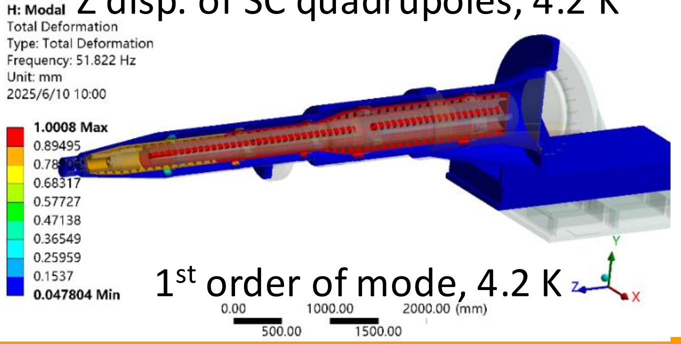
Analyses model



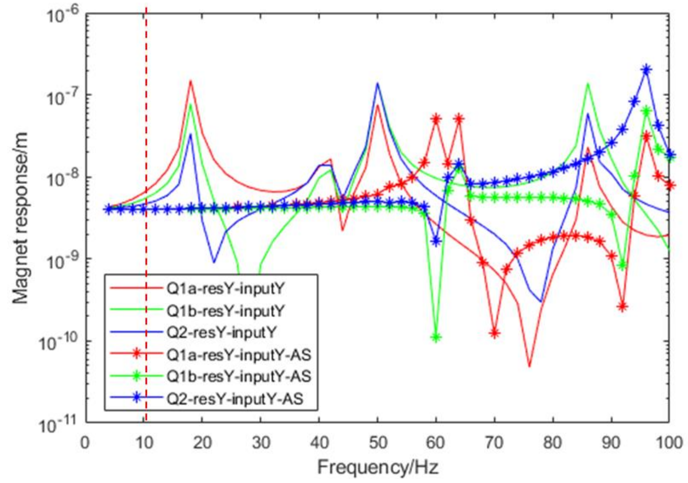
Primary concerned metrics



Z disp. of SC quadrupoles, 4.2 K



1st order of mode, 4.2 K



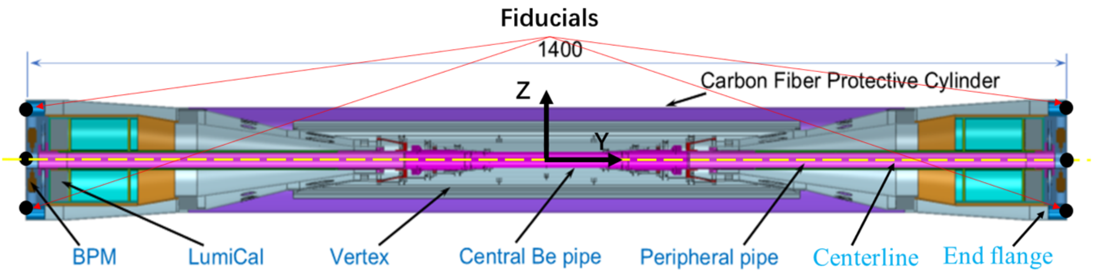
Harmonic response, 1-100Hz

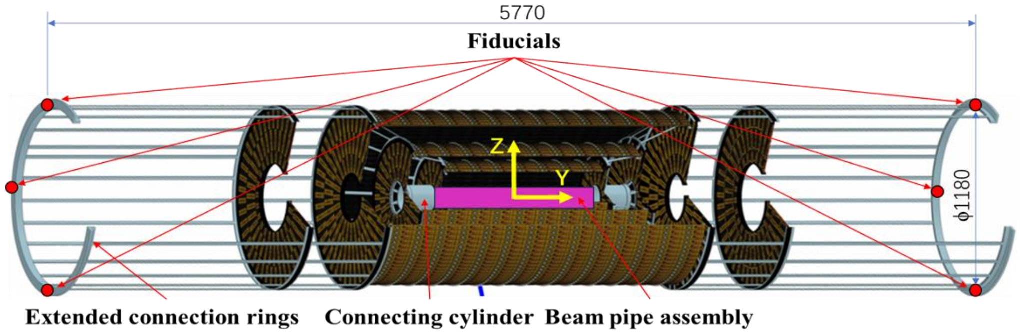
Details in: Haijing Wang, Mini-Review of CEPC MDI (9-June 10, 2025), https://indico.ihep.ac.cn/event/26255/

MDI alignment

- Components in MDI need to be aligned mainly include Beam pipe, LumiCal, BPM and Cryostat (final focusing magnets).
- Beam pipe assembly integrates beam pipe, vertex detector, LumiCal, and BPM.
- Beam pipe assembly installed in ITK, its finally alignment accuracy is 100um.

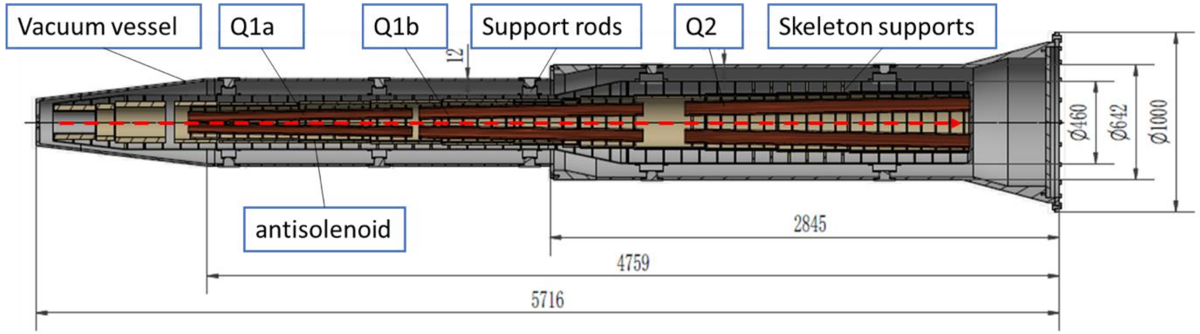
Beam pipe assembly





ITK

Cryostat internal structure



- Cryostat alignment scheme
  - LHe-tank module fiducialization
  - Cryostat pre-alignment
  - Cryostat installation alignment

Alignment accuracy of the SCQs on both sides ≤ 100μm