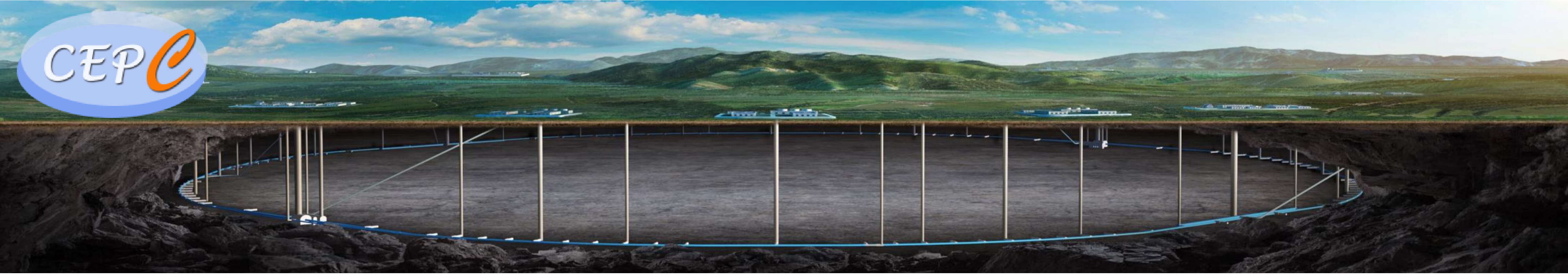

CEPC Detector Mechanical integration

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Institute of High Energy Physics
Chinese Academy of Sciences

Oct. 22th, 2024, CEPC Detector Ref-TDR Review

Content

- Introduction
- Requirements
- Technical challenges
- Comparison and selection of different schemes
- Overall installation design
- Research team
- Summary and working plan

Introduction

CEPC Detector Mechanical integration : (R&D content)

1. Draw and optimize the detectors overall mechanical layout drawing
   Based on the design requirements of the sub-detectors and its electronics
2. Design and optimize the connection structure between the sub-detectors
   Based on(After have completed) each sub-detectors structure design
3. Plan and optimize installation steps for each sub-detector

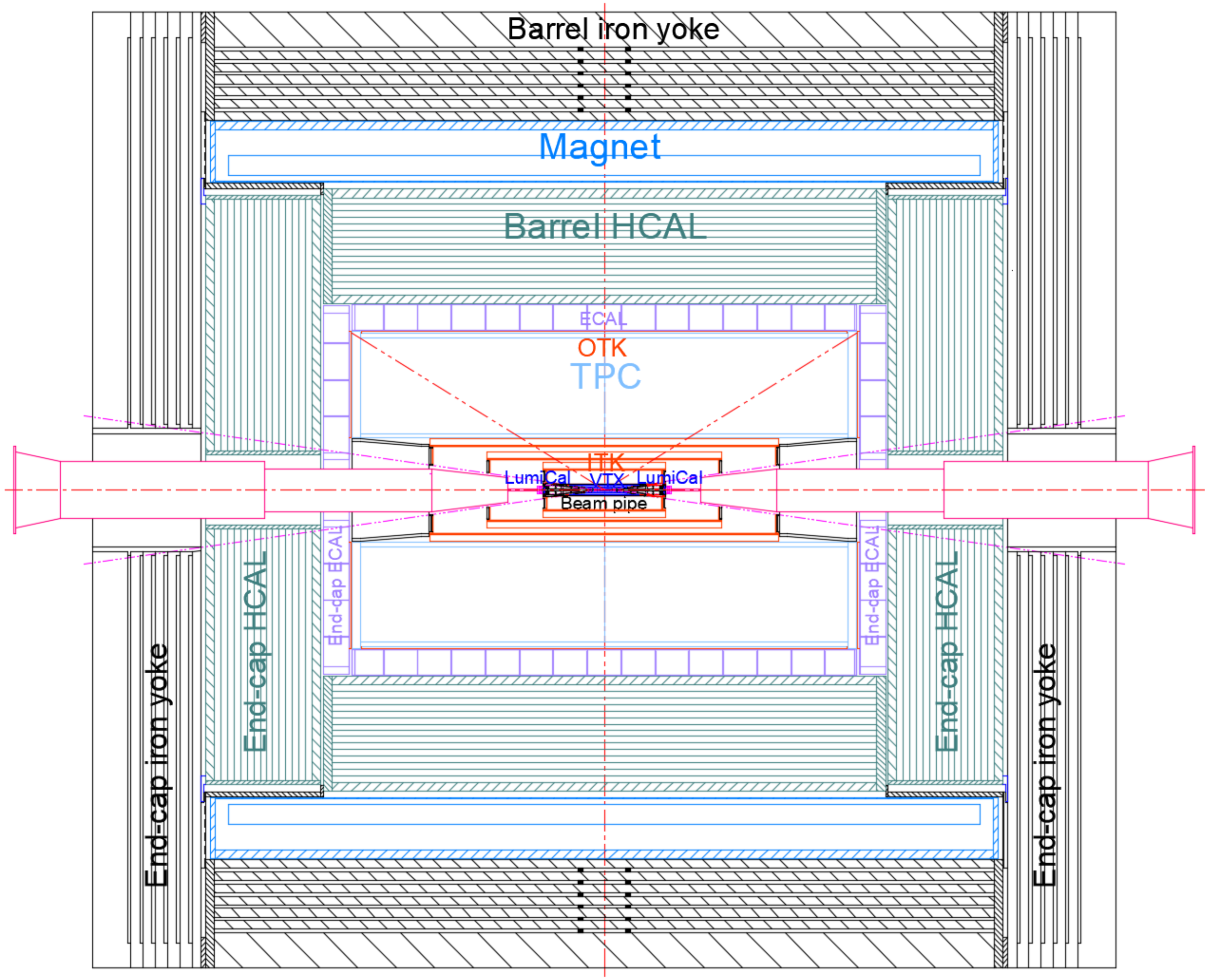
4. Plan and optimize layout and configuration of the underground experiment room
   Vertical shaft hoist and lifting equipment , etc.
5. Others (underground auxiliary room , ground room)

Introduction

1. Detectors overall mechanical layout drawing :

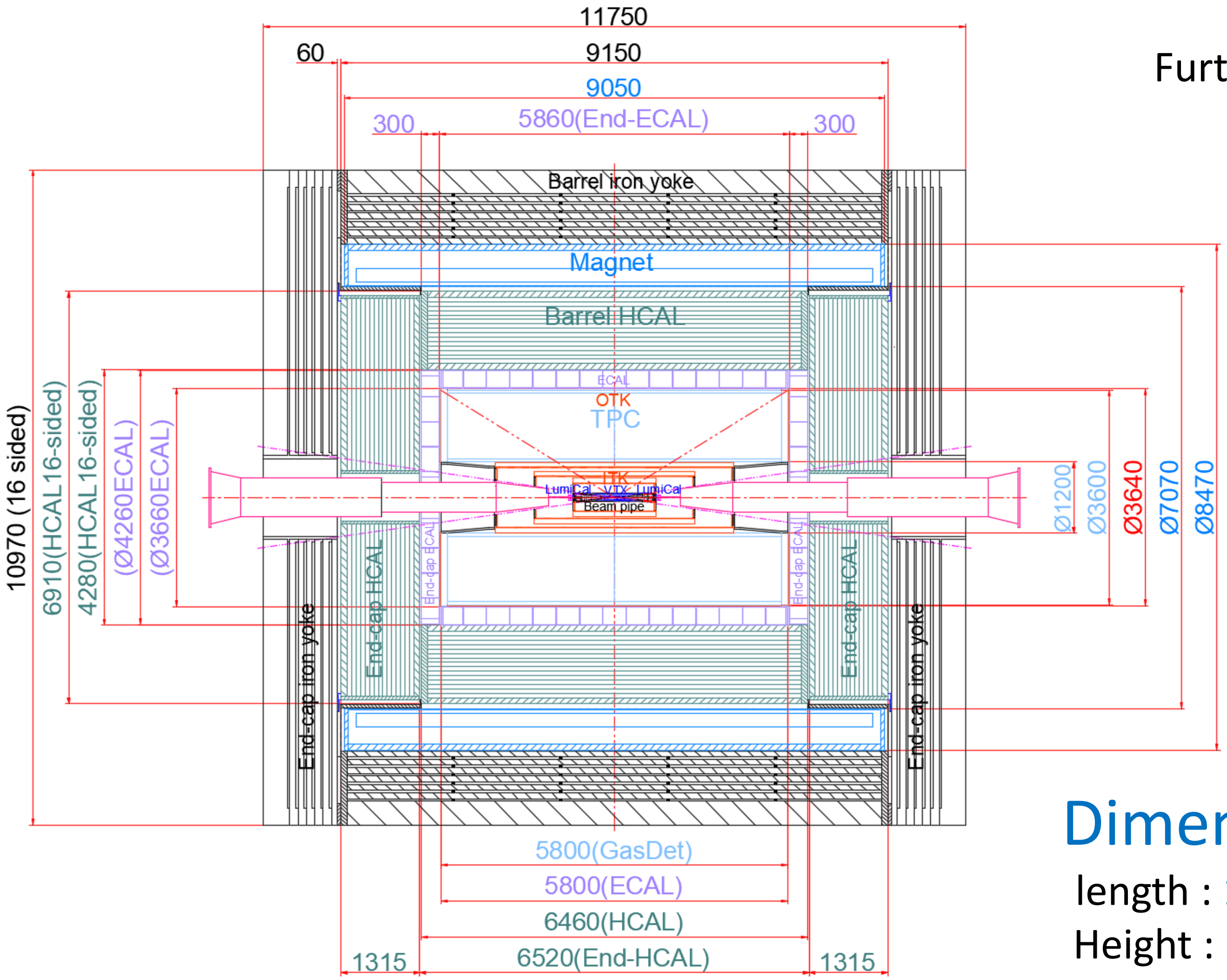
From outside to inside

Barrel(7)	End(3)
Yoke (Muon)	Yoke (Muon)
Magnet	HCAL
HCAL	ECAL (OTK)
ECAL	
TPC (OTK)	
ITK	
Beampipe (VTX LumiCal)	

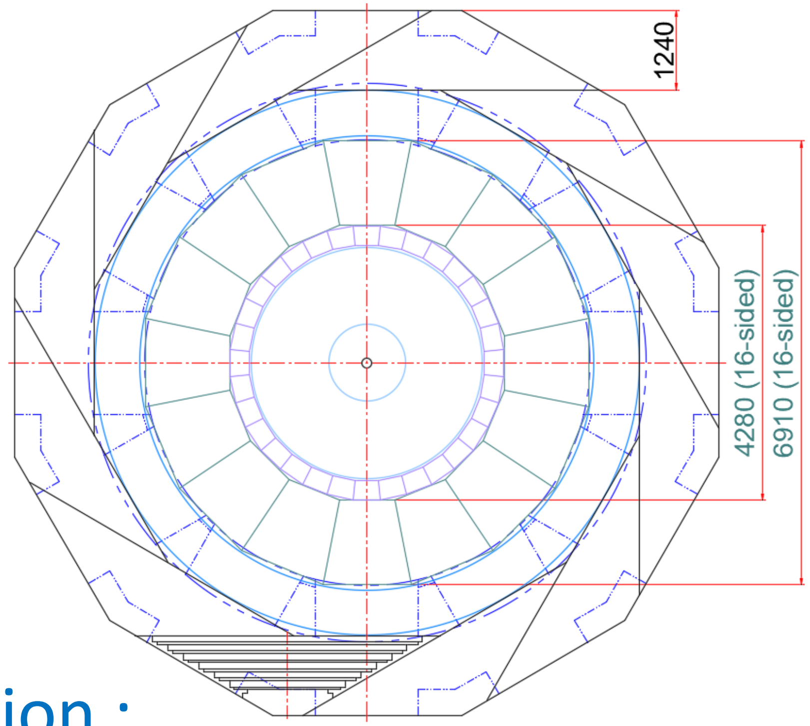


Introduction

2. Initial size distribution :



Further optimization and improvement are needed



Dimension :

length : 11750 mm

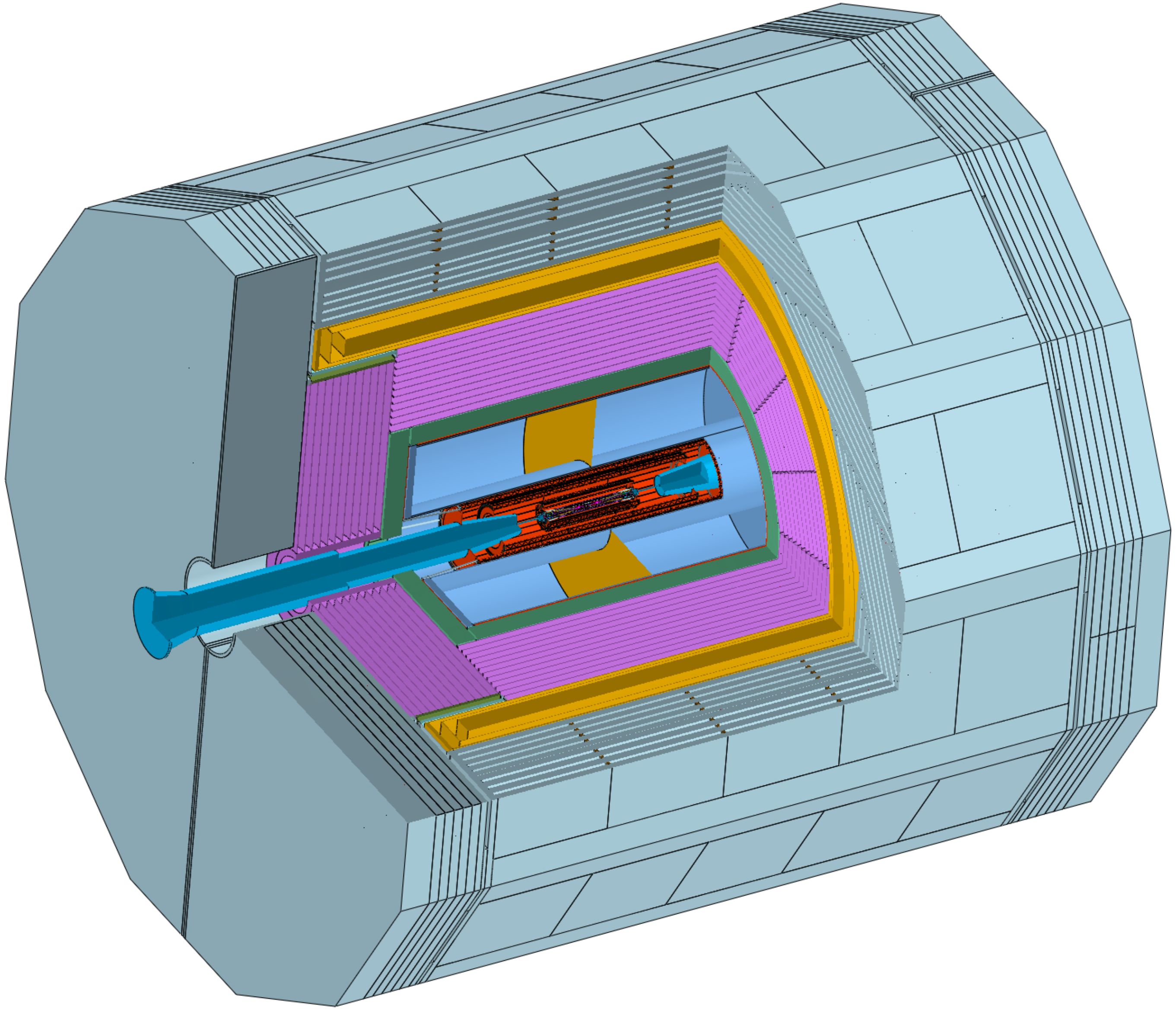
Height : 10970 mm

Introduction

Total weight :

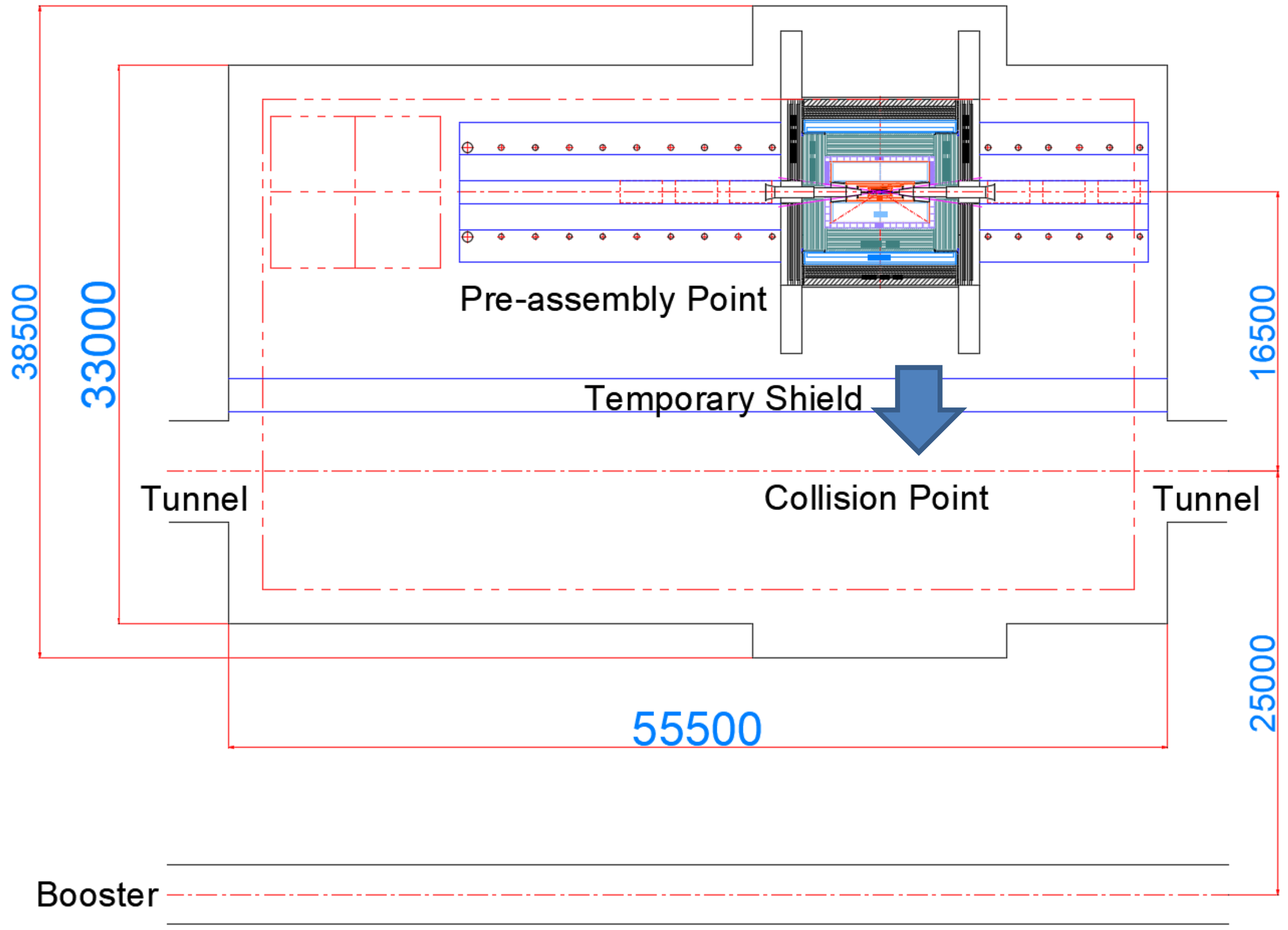
≈ 6000 t

Yoke : ≈ 3800 t
Magnet : ≈ 265 t
HCAL : ≈ 1720 t



Introduction

3. Layout of installation scheme for “Pre-assembly point“ :



This is a very compact design

Installation location :

Pre-assembly point

Requirements

1. Installation Clearance and accuracy :

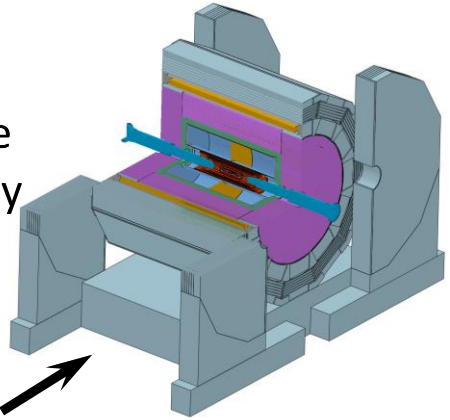
Minimum gap principle :
As small as possible

Profile Tolerance(mm)		installation accuracy(mm)		positioning accuracy Coaxiality(mm)
		Collimation accuracy (mm)	GAP (mm)	
Yoke	± 1	< 1		±0.5
Magnet	Outer: 0 to -5, inner: 0 to +5	< 2	10	± 1
HCAL	Outer: 0 to -5, inner: 0 t0 +5	± 2	10	± 0.5
ECAL	Outer: 0 to -5, Inner: 0 t0 +5	± 2	10	± 0.5
TPC	Outer: 0 to -2, Inner: 0 t0 +2	± 1	5	± 0.1
ITK	Outer: 0 to -2, Inner: 0 t0 +2	± 1	5	± 0.1
Beampipe	Outer: 0 to -0.3, Inner: 0 t0 +0.3	± 0.5	2	± 0.1

Requirements

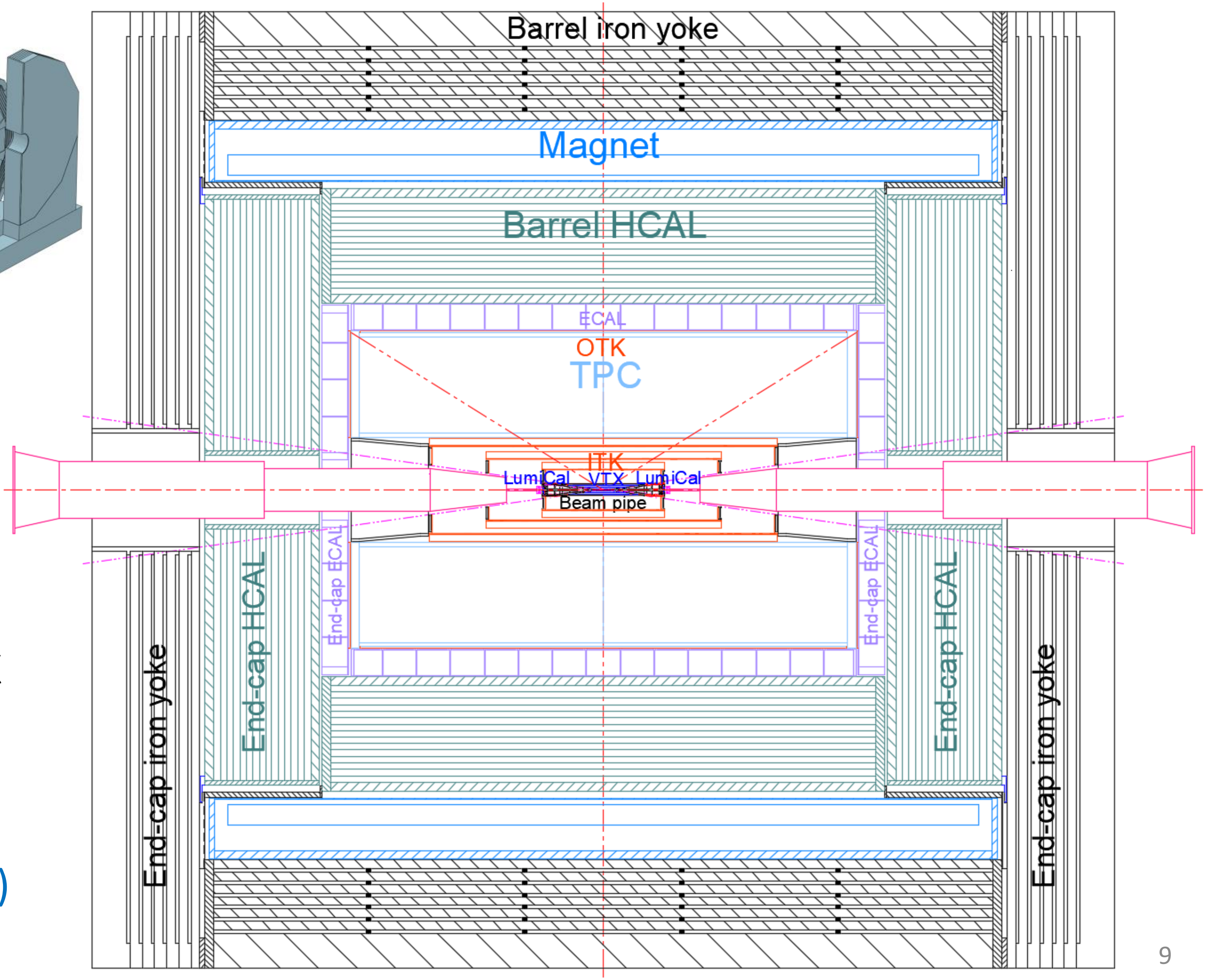
Connection design :

The design of the connection structure should follow the principle of proximity connection



Barrel Yoke : Fixed on the Base
Magnet : Fixed on the Barrel Yoke
Barrel HCAL : Fixed on the Barrel Yoke
Barrel ECAL : Fixed on the Barrel HCAL
TPC+OTK : Fixed on the Barrel ECAL
ITK : Fixed on the TPC
Beampipe(Vertex and LumiCal) : Fixed on the ITK

End-cap ECAL+OTK : Fixed on the Barrel HCAL
End-cap HCAL : Fixed on the Barrel HCAL
(Auxiliary cylinder or Flange)
End Yoke : Fixed on the Base



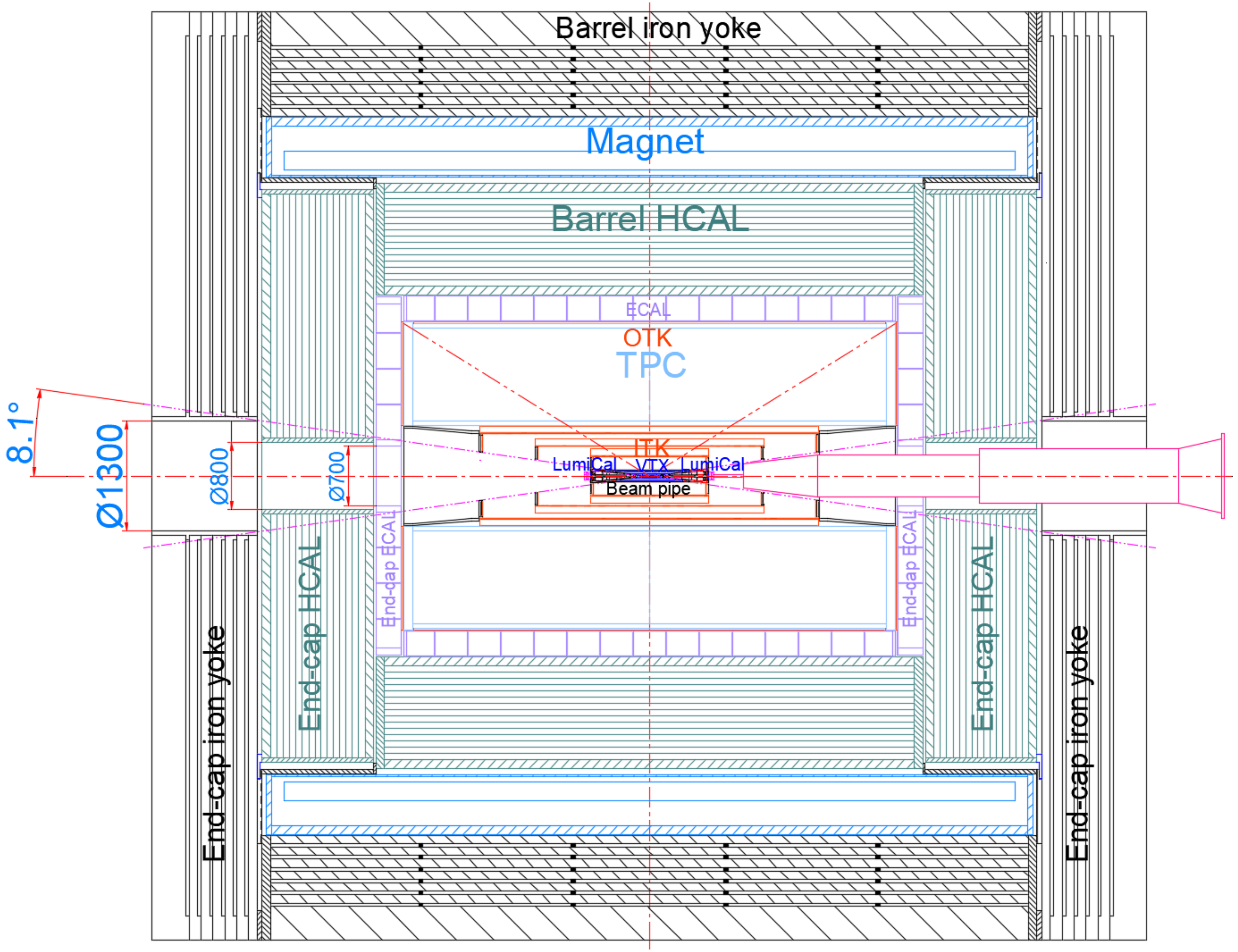
Requirements

MDI boundary

Consists of 4 channels :

Detection angle : 8.1 ° (arccos0.99)
(Before ECAL)

(After ECAL)
ECAL : 700 X 700 mm
HCAL : Ø800 mm
Yoke : Ø1300 mm

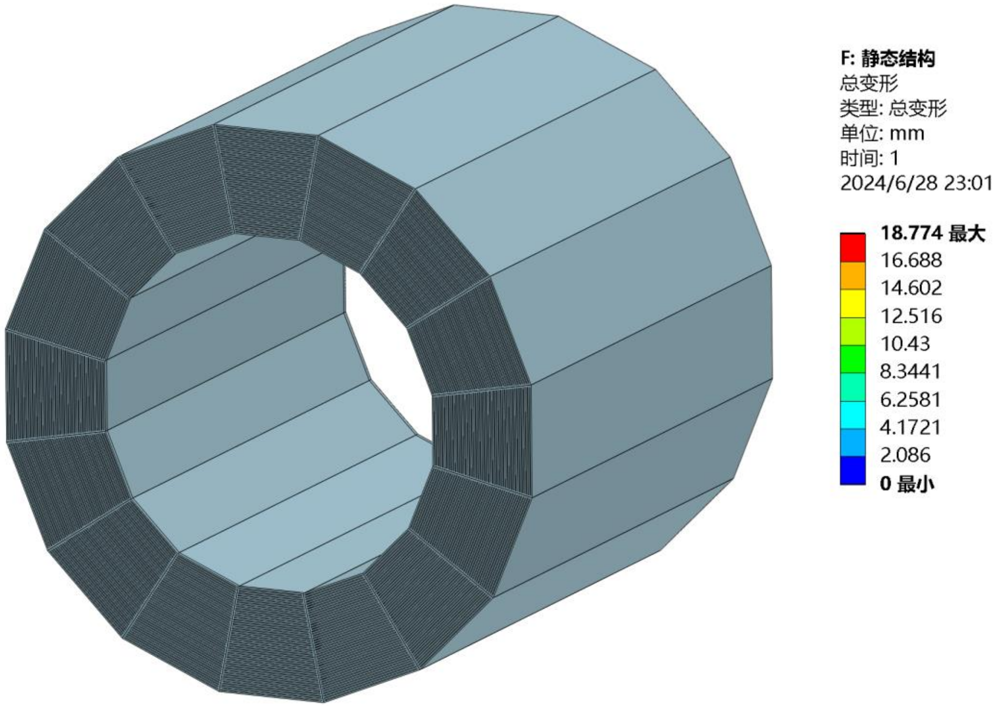


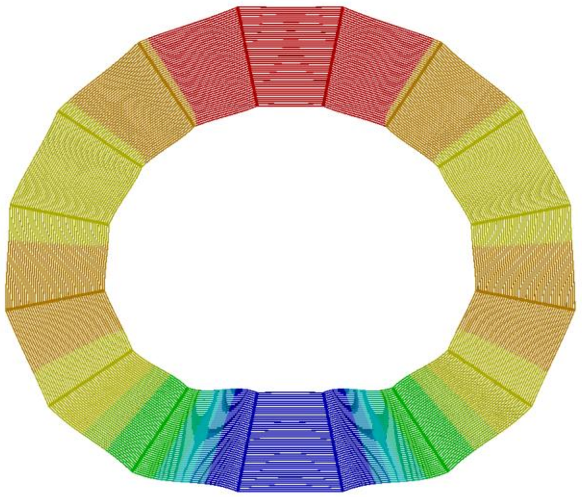
Conical hole and stepped holes are reserved spaces for accelerators

Technical challenges

In the current mechanical design process, we encounter many technical challenges:

1. The contradiction between self weight deformation and installation clearance





Key :

Deformation must be controlled through mechanical optimization design

Requirements :

GAP between HCAL and Magnet : 10 mm

GAP between HCAL and ECAL : 10 mm

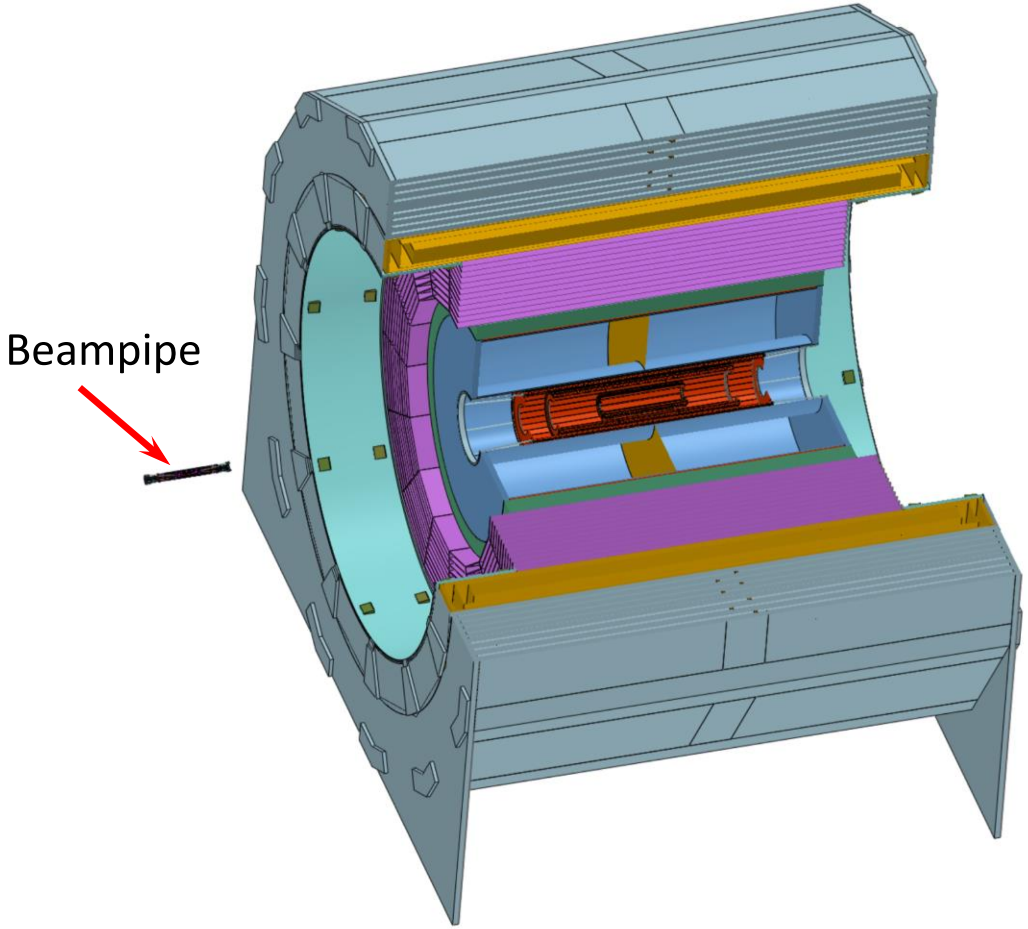
Self weight deformation :

18.8 mm (> 10mm)

Technical challenges

In the current mechanical design process, we encounter many technical challenges:

2. Installation, fixation, and adjustment of beam pipe



Difficulties :

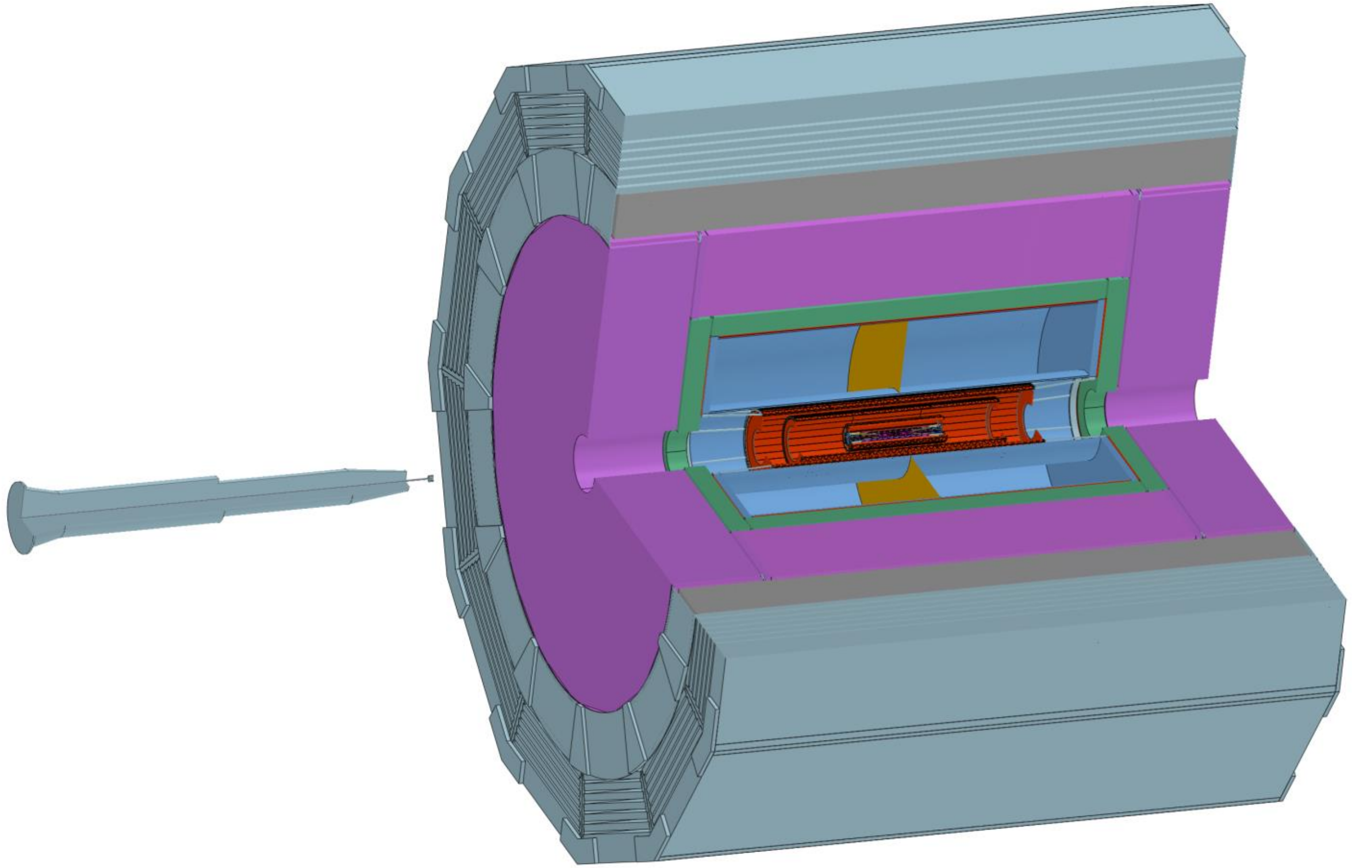
Long distances

Small operating space

Technical challenges

In the current mechanical design process, we encounter many technical challenges:

3. Connection between the Acc MDI component and the Be beampipe



This is a connection design that cannot be operated using conventional methods

Technical difficulties :

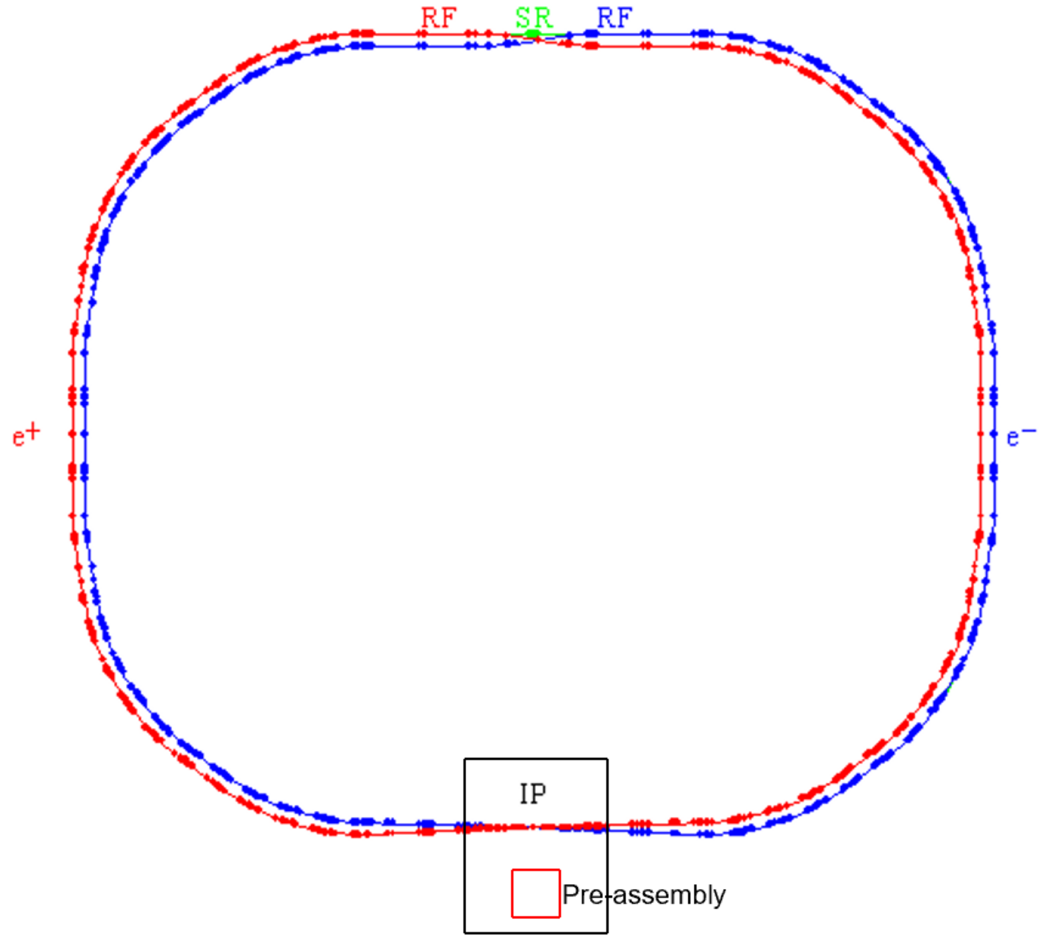
leak rate : 2.66 X 10 $^{-11}$ Pa *m^3 /s

Need to improve and develop current technology

Pillow seal maybe used for remote vacuum automatic connection

Comparison and selection of different schemes

Comparison and selection of the detectors installation Position



Collision point **or** Pre-assembly point ?

Based on previous design experience :

Collision point scheme :

Advantage : **Small installation space**

Disadvantage : Low installation efficiency and high time risk

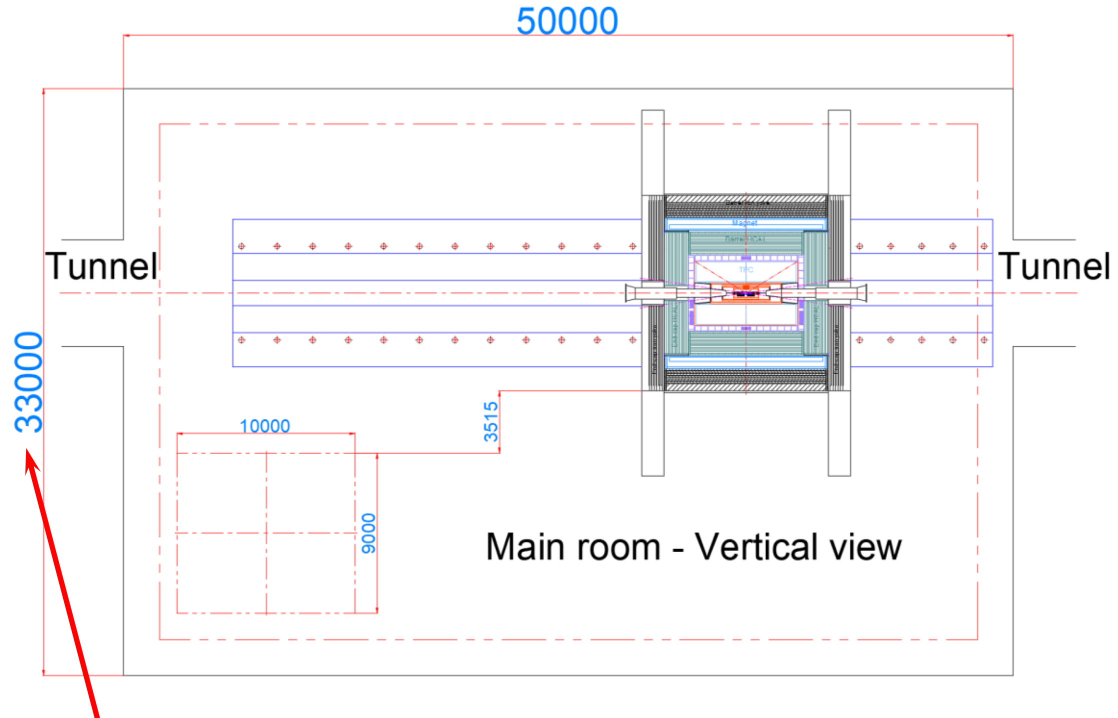
Pre-assembly point scheme :

Advantage : High installation efficiency and low time risk

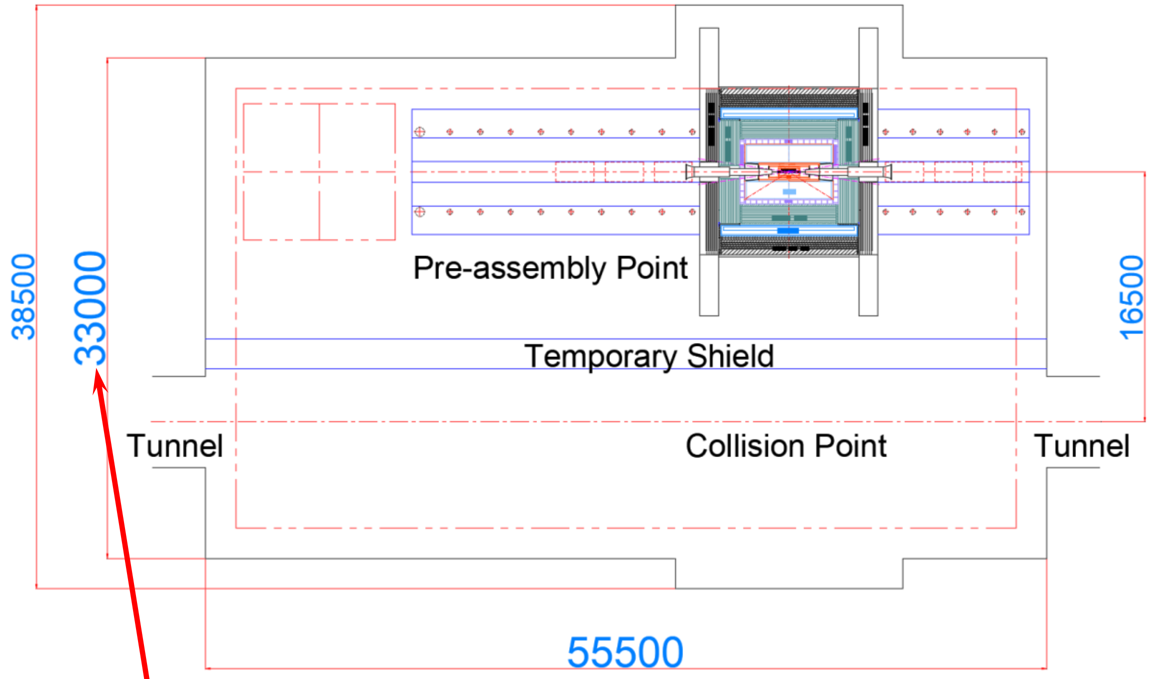
Disadvantage : **Large installation space**

Comparison and selection of different schemes

Comparison and selection of the detectors installation Position



Collision Point Scheme



Pre-assembly Point Scheme

Conclusion :

Choose Pre-assembly point scheme (…)

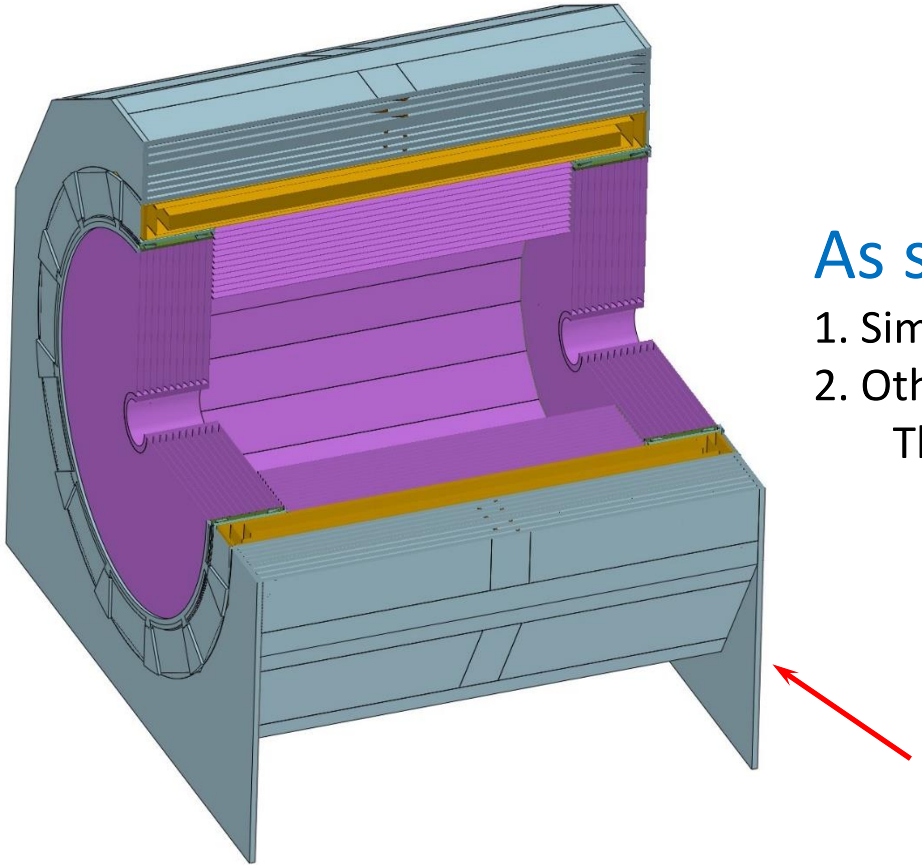
Overall installation design

Overall installation design:

1. Reliability and safety assessment of integral detectors and their connecting structures
   (FEA --- stress and deformation)
2. Overall installation steps
3. Installation sequence of the detectors
4. Modular lifting and integral lifting of components

Overall installation design

1. Overall reliability and safety assessment



Key :

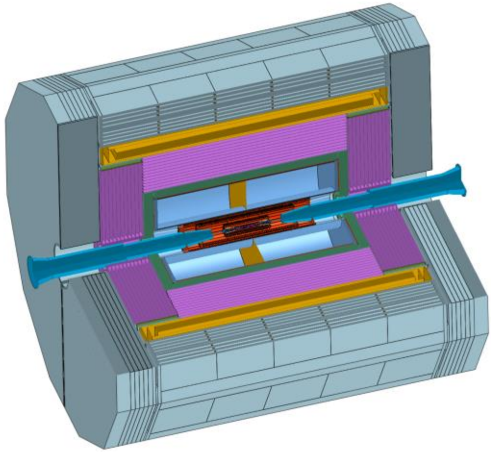
Deformation and stress of the Yoke and the connection structure

(Yes ? No)

As shown in the left figure:

1. Simplified the connection structure between the Yoke, Magnet and HCAL
2. Other lighter components are ignored

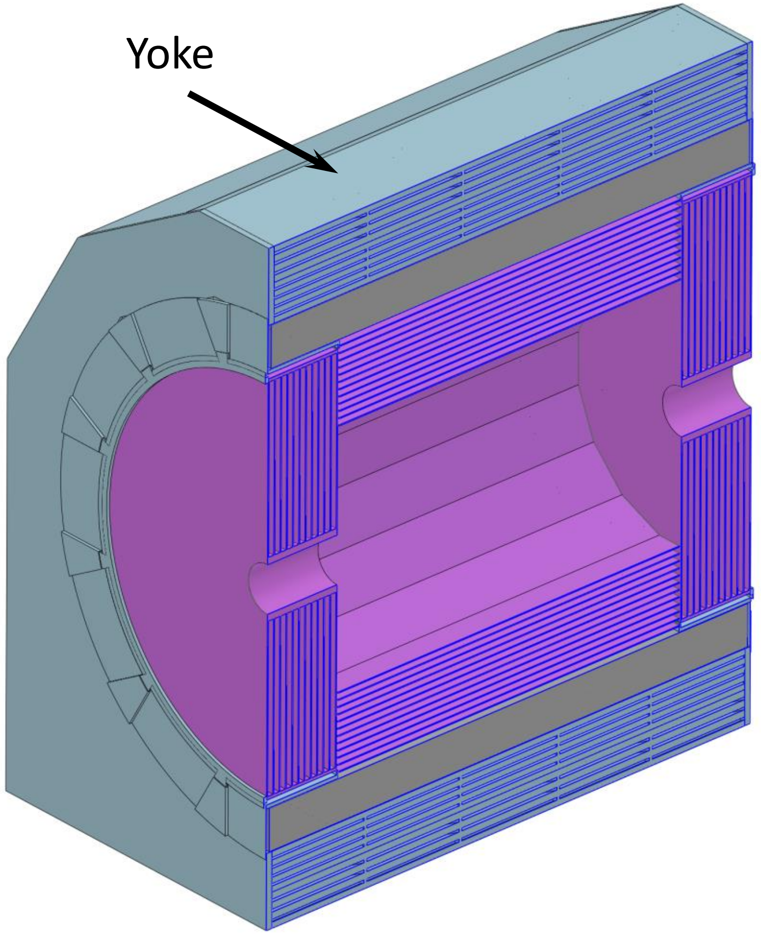
These components do not affect the calculation results and overall assessment



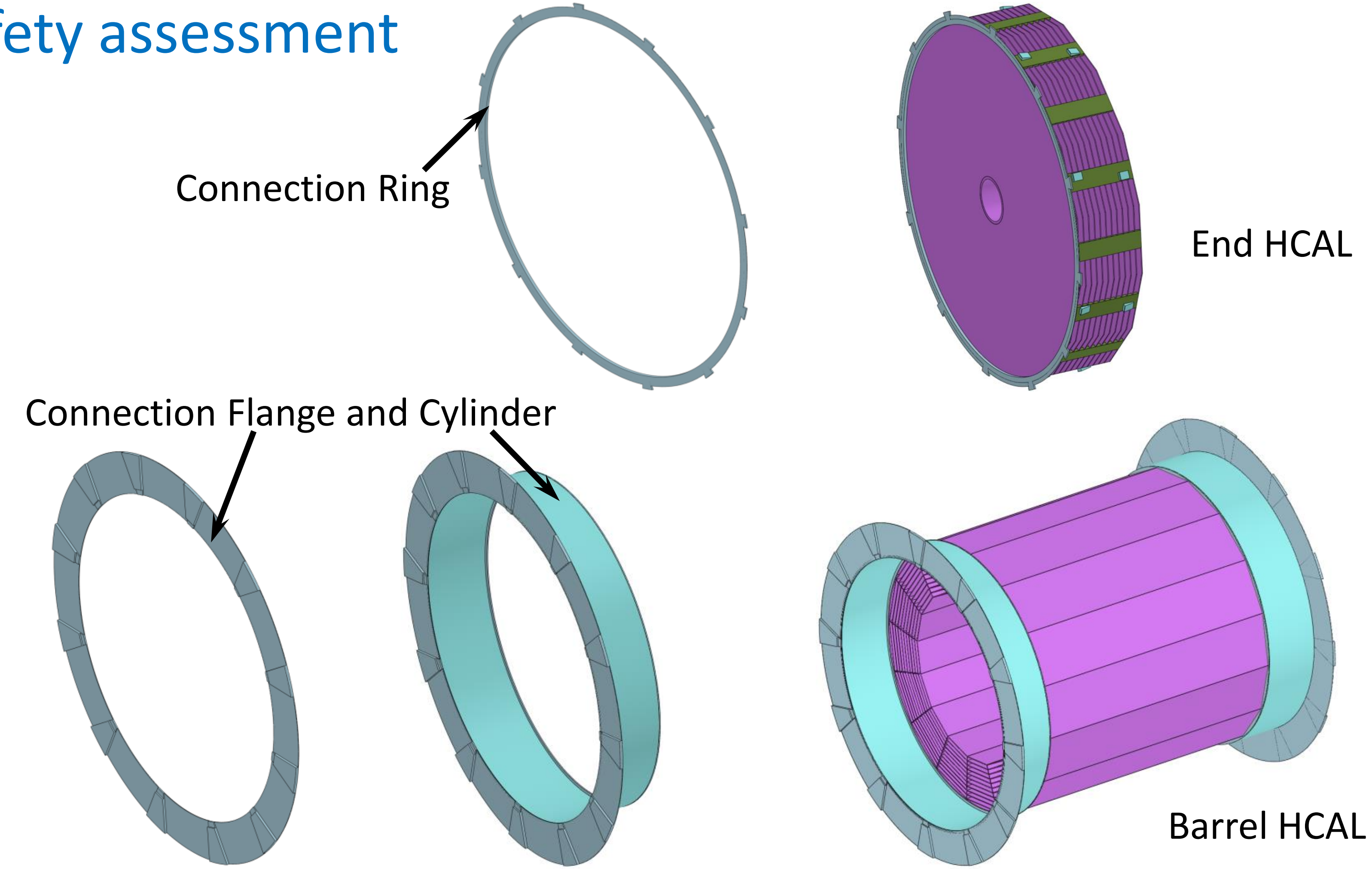
Axial segmentation from 5 to 2 segments

Overall installation design

1. Overall reliability and safety assessment



Focus on the deformation of the Yoke



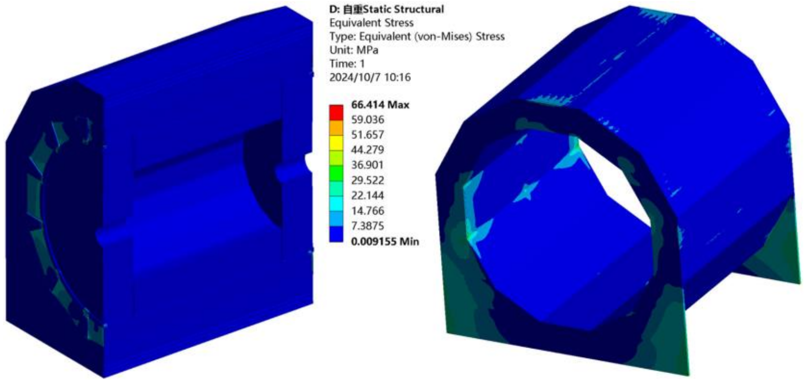
Putting the connection structure of HCAL and Magnet into a computational model

Overall installation design

1. Overall reliability and safety assessment

Conclusion : Safety

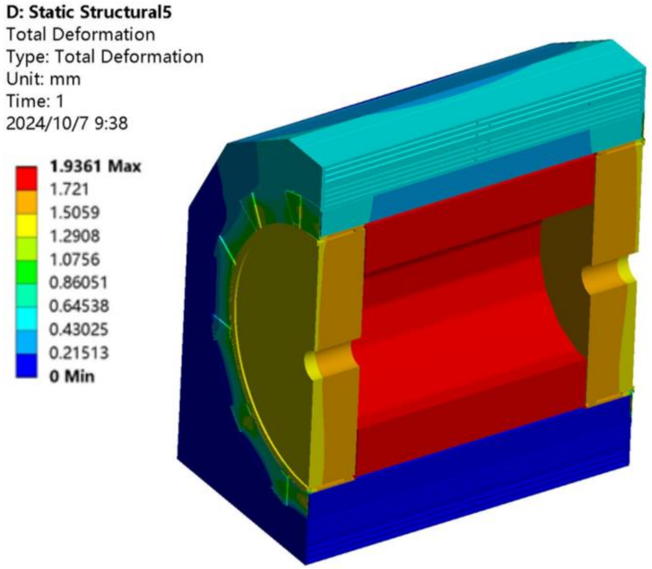
Stress cloud of the Yoke



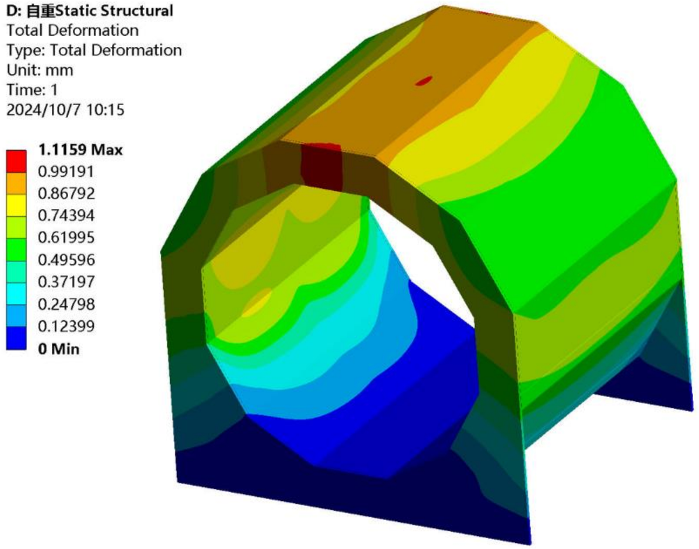
With detectors   Without detectors

Max Stress : ≈ 70 MPa

Deformation cloud of the Yoke



With detectors



Without detectors

Max Deformation : ≈ 1.9 mm

Max Deformation : ≈ 1.2 mm

Advantages of Spiral Structure：

1. No detector blind spots
2. Install the detector from the side for easy maintenance
3. Axial segmentation increases rigidity

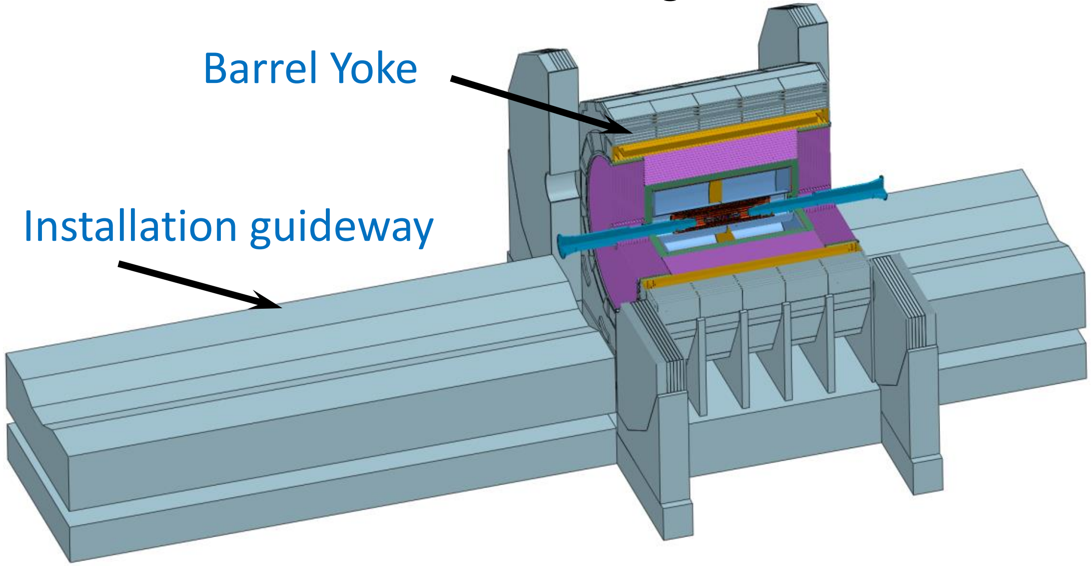
Suggestion : Continue to deepen the design of detectors

(Reduce the deformation caused by installing detectors)

Overall installation design

2. Overall installation steps

General installation drawing



Note :

Installation guideway is the installation reference, and must be pre-collimation with yoke

The steps are as follows :

1. In the ground room

Complete the assembly work of each sub-detector, including electronics, etc.

2. In the shaft

Each sub-detector is lifted into the underground experimental hall through vertical shaft in sequence

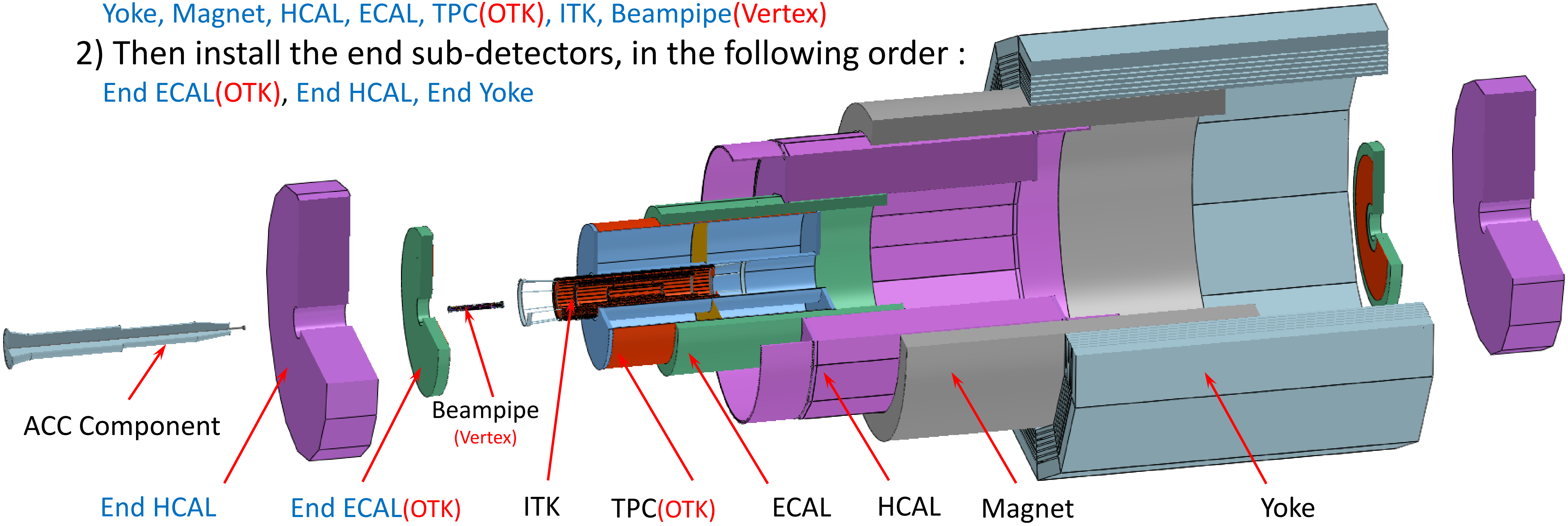
3. In the underground experimental Hall

Assemble each sub detector on the installation guideway and push them into the yoke in sequence

Overall installation design

3. Installation sequence of detectors (As shown in the exploded view)

1) Install the barrel sub-detector first, in the following order :
   Yoke, Magnet, HCAL, ECAL, TPC(OTK), ITK, Beampipe(Vertex)
2) Then install the end sub-detectors, in the following order :
   End ECAL(OTK), End HCAL, End Yoke



Overall installation design

3. Installation sequence of detectors

3) Installation process --- Different detectors use different installation methods

Barrel Detectors

3.1) Mixed alternating installation : Yoke and Magnet (2)

3.2) Core shaft method installation : Barrel HCAL and Barrel ECAL (2)

3.3) Cantilever method installation : TPC(OTK) ITK Beampipe(Vertex + LumiCal) (3)

End Detectors

Cantilever method installation : ECAL(OTK) HCAL (2)

3.4) Move the detectors from the Pre-assembly point to Collision point

Overall installation design

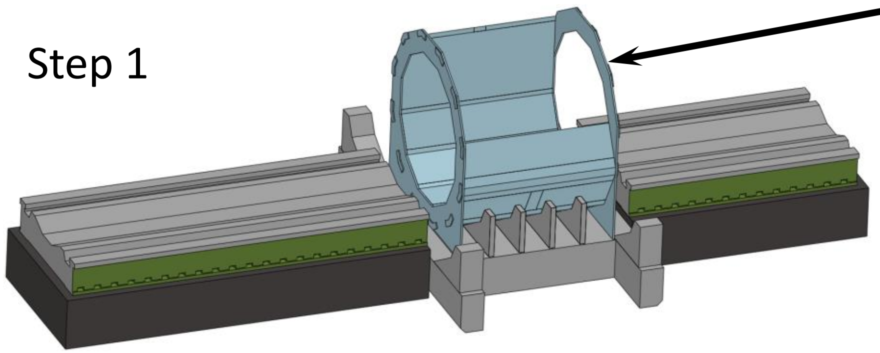
3. Installation sequence of detectors

3) Installation process --- Different detectors use different installation methods

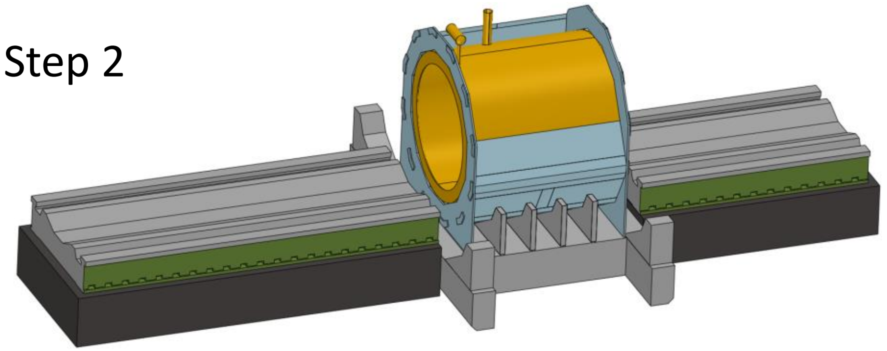
3.1) Mixed alternating installation : Yoke and Magnet (2)

The installation design of the yoke "zero auxiliary tooling" provides a possibility for mixed installation

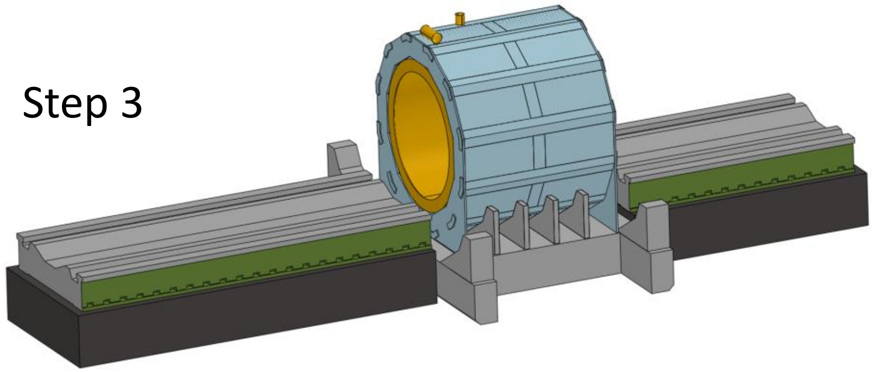
Step 1



Step 2



Step 3



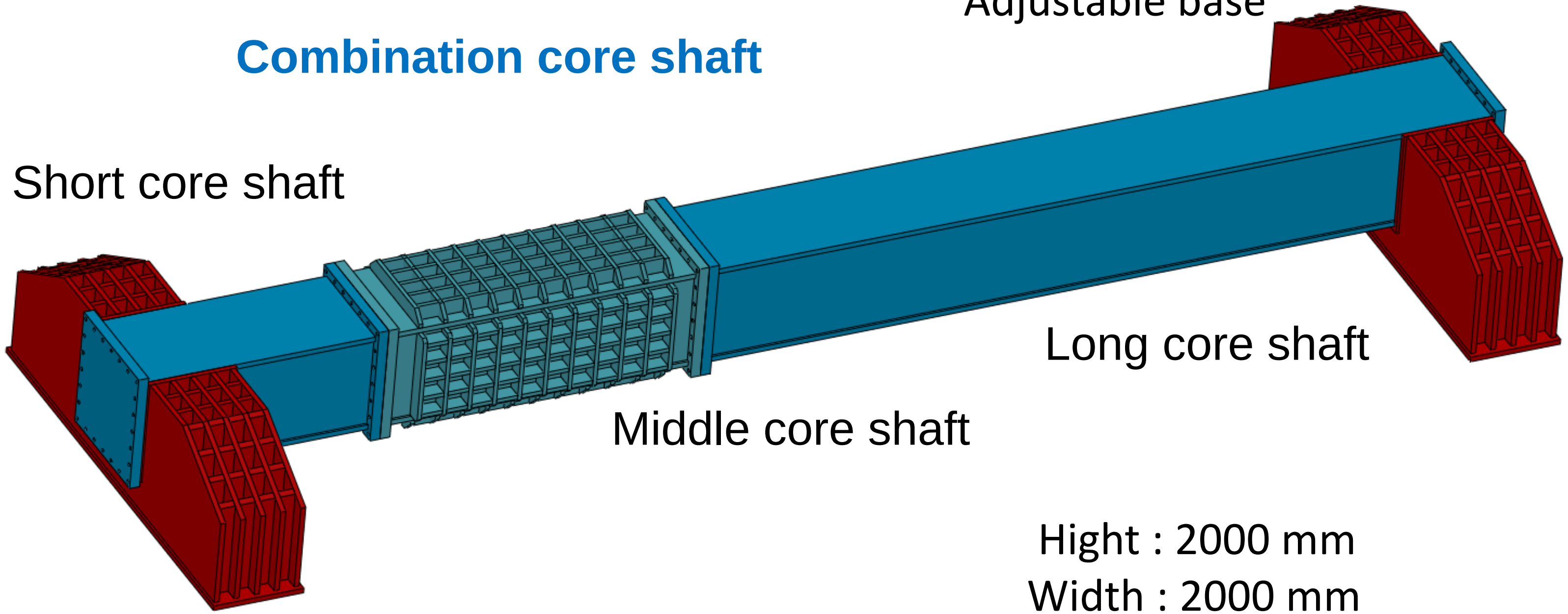
Step 1 : Install two end flanges and the lower half of the Yoke module
Step 2 : Install Magnet
Step 3 : Install the upper half of the Yoke module

Overall installation design

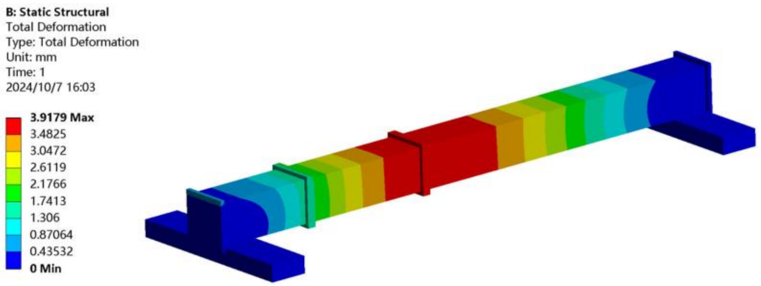
3. Installation sequence of detectors

3.2) Core shaft method installation : Barrel HCAL and Barrel ECAL (2)

Taking HCAL as an example, introduce the installation process of the core shaft method



Hight : 2000 mm
Width : 2000 mm
Length : 27300 mm



Load :

1. Self-weight
2. 1000 ton HCAL simulated load

Max Deformation : ≈ 3.9 mm

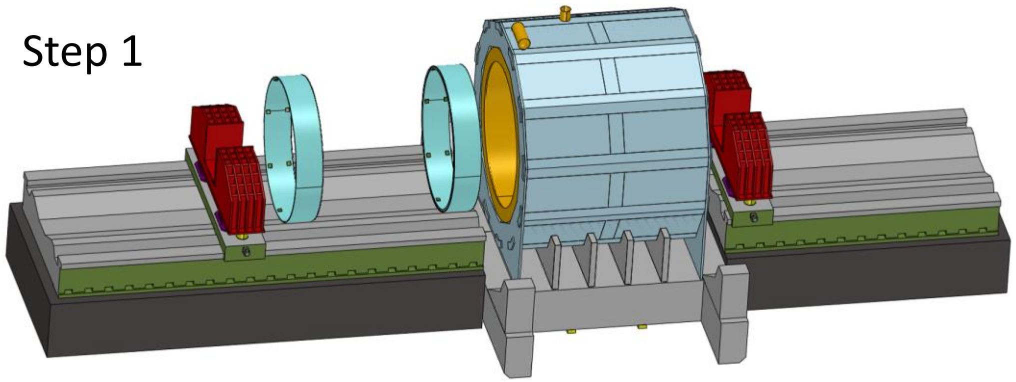
Overall installation design

3. Installation sequence of detectors

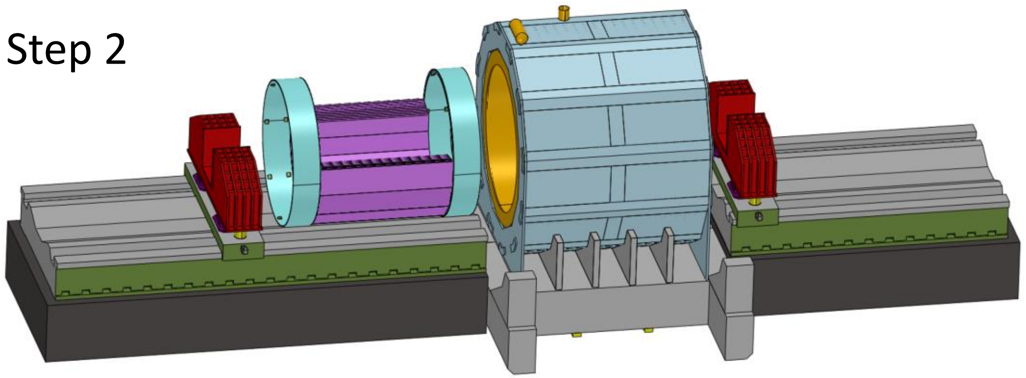
3.2) Core shaft method installation : Barrel HCAL and Barrel ECAL (2) --- Barrel

Taking HCAL as an example, introduce the installation process of the core shaft method

Step 1



Step 2



Step 1 : Two auxiliary rings (these two rings are both part of the components, and auxiliary installation tools)
Step 2 : The lower half of the HCAL module

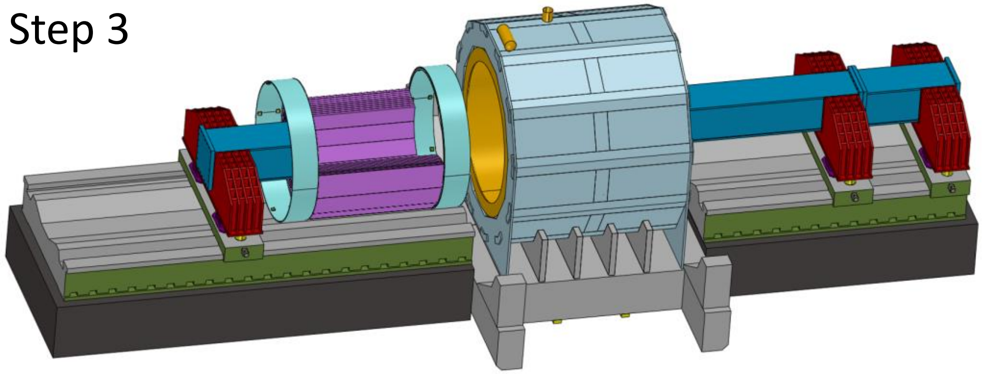
Overall installation design

3. Installation sequence of detectors (Installation process of composite core shaft)

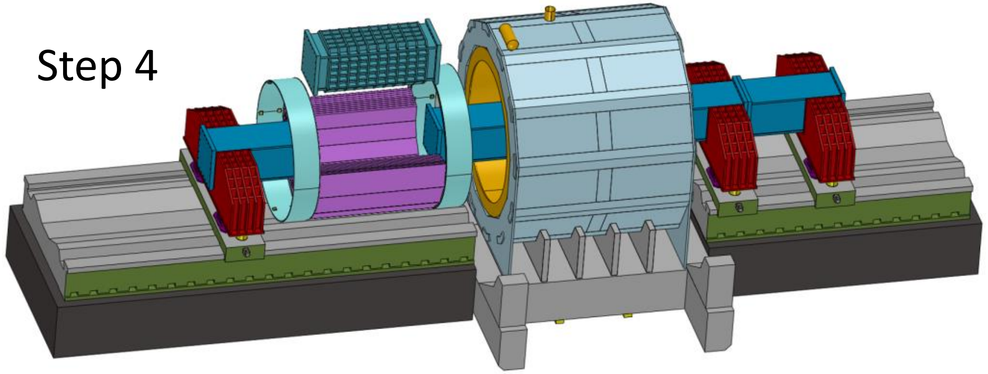
3.2) Core shaft method installation : Barrel HCAL and Barrel ECAL (2) --- Barrel

Taking HCAL as an example, introduce the installation process of the core shaft method

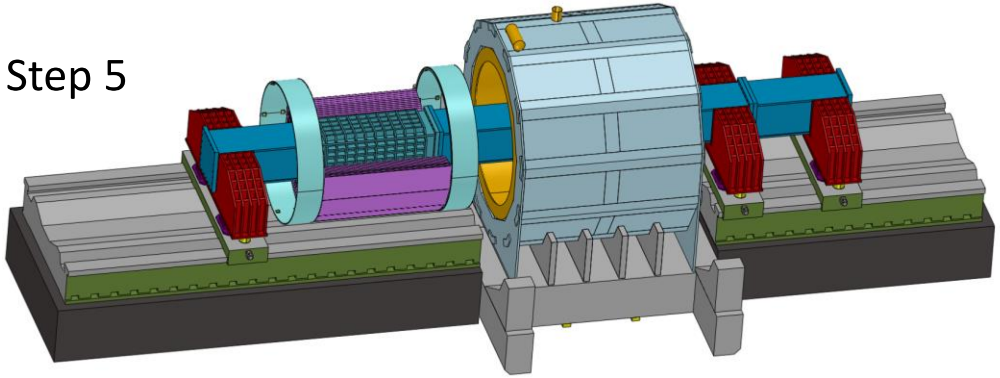
Step 3



Step 4



Step 5



Step 3 : Install short core shaft and long core shaft
Step 4 : Hang in the middle core shaft
Step 5 : Complete the assembly of the core shaft

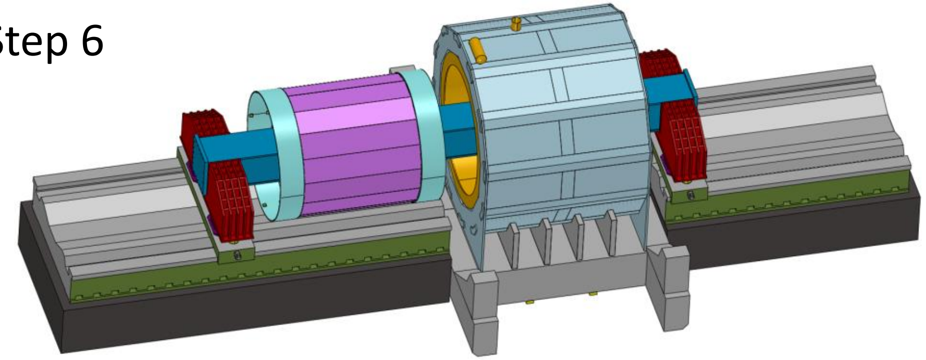
Overall installation design

3. Installation sequence of detectors

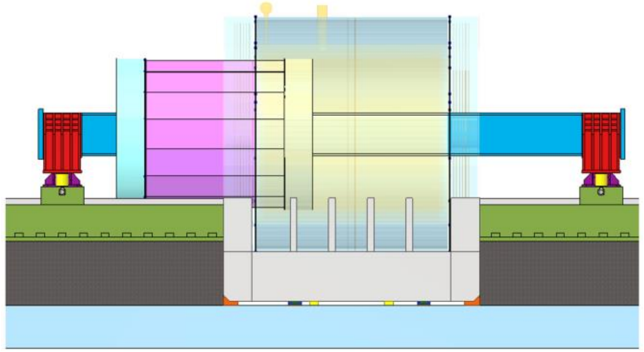
3.2) Core shaft method installation : Barrel HCAL and Barrel ECAL (2) --- Barrel

Taking HCAL as an example, introduce the installation process of the core shaft method

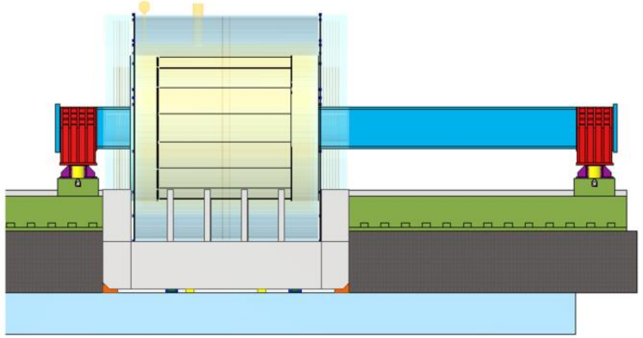
Step 6



Step 7



Step 8



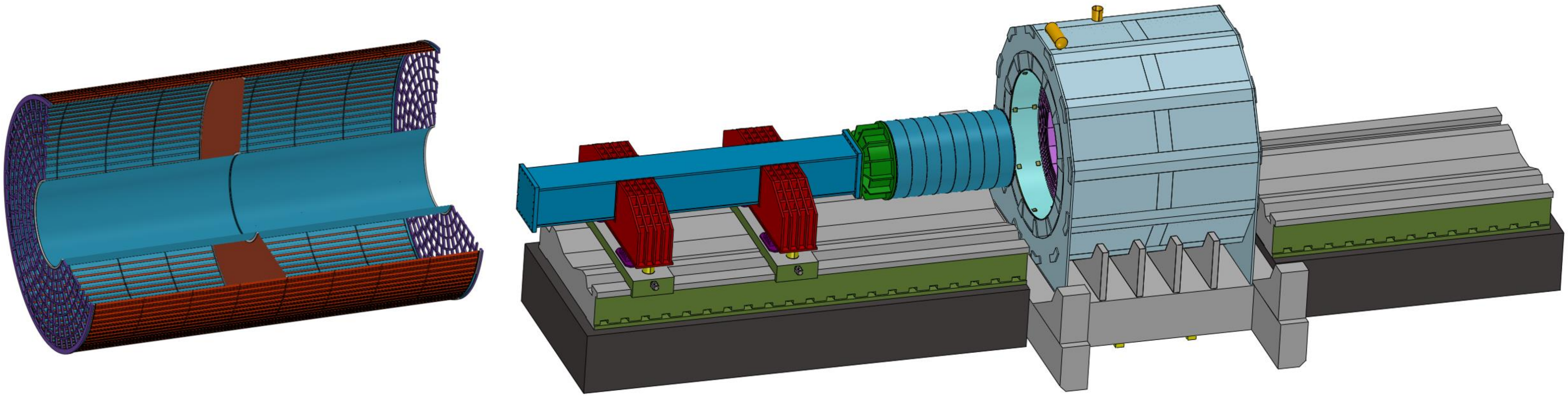
Step 6 :
Step 7 :
Step 8 :

Overall installation design

3. Installation sequence of detectors

3.3) Cantilever method installation : TPC(OTK)   ITK   Beampipe(Vertex + LumiCal) (3) --- Barrel

Taking TPC(OTK) as an example, introduce the installation process of the Cantilever method



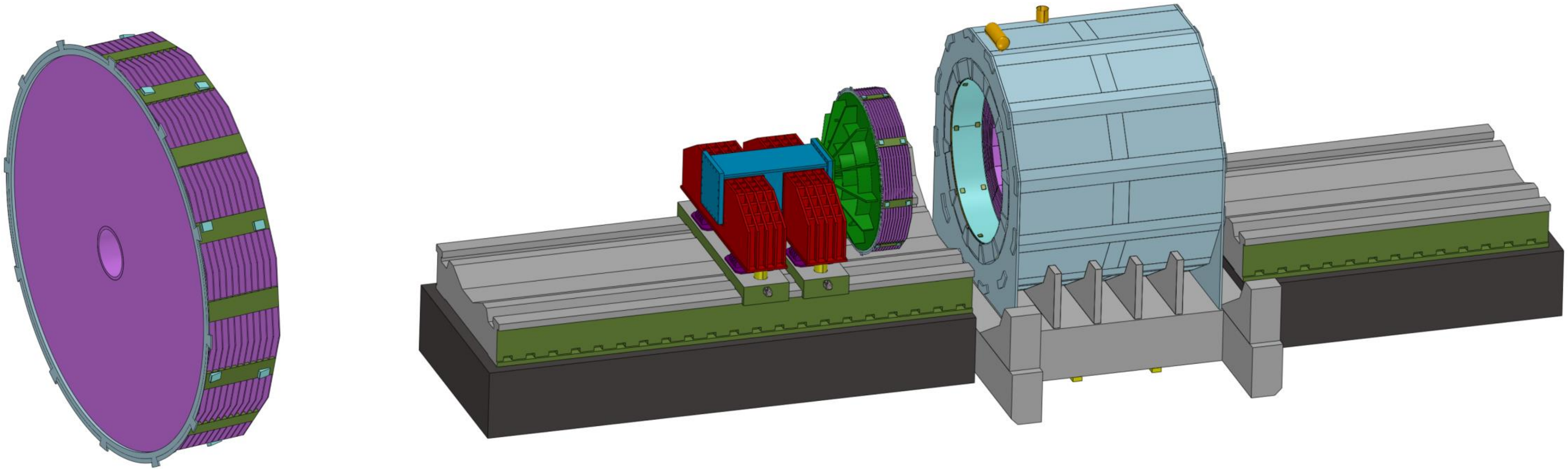
Note : Different detectors have different fixing and adjustment methods, This is also the focus of our future design

Overall installation design

3. Installation sequence of detectors

3.3) Cantilever method installation : ECAL(OTK) HCAL (2) --- End

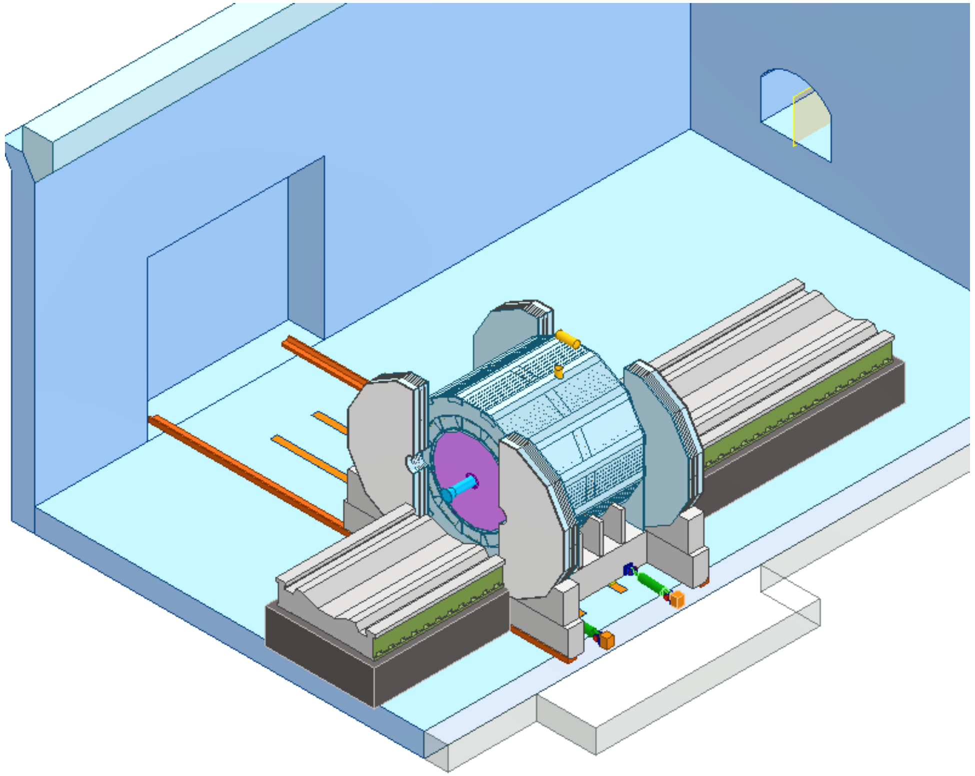
Taking HCAL as an example, introduce the installation process of the Cantilever method

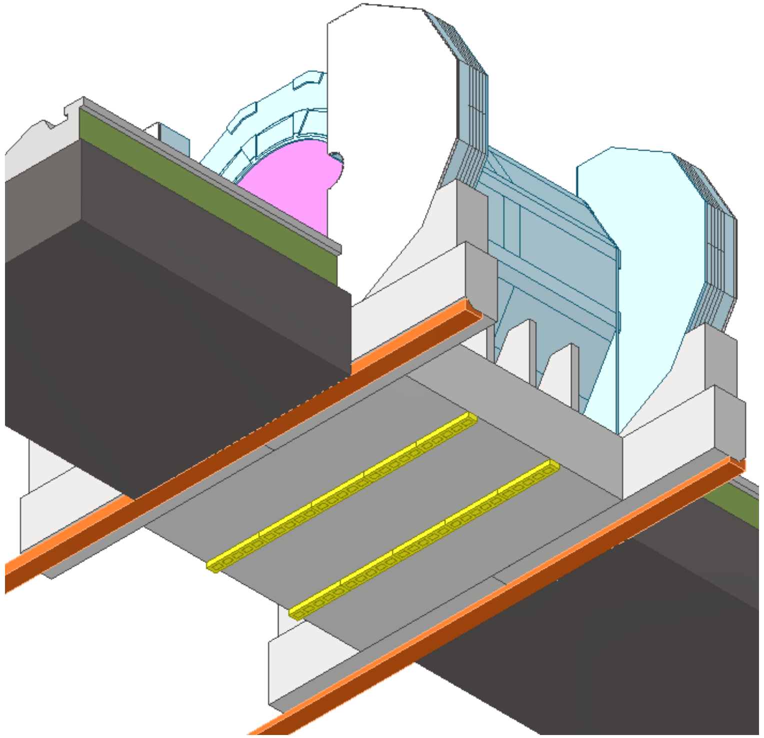


Overall installation design

3. Installation sequence of detectors

3.4) Move the Detectors from Pre-assembly point to Collision point

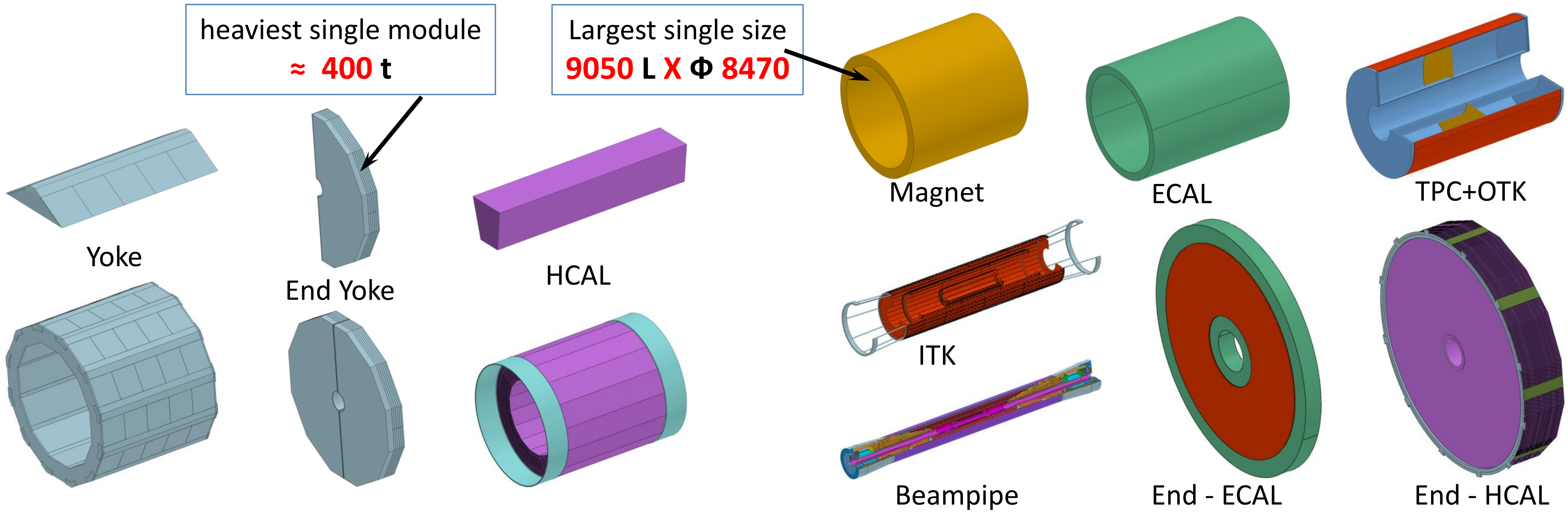




Overall installation concept design

4. Modular lifting and integral lifting for components : (relates to the design of the shaft and the hoists)

Modular lifting **Integral lifting**



Research team

Team characteristics:

1. Optimize and configure the engineering design team with the mechanical engineers from the High Energy Institute as the core
2. Resource allocation is comprehensive and reasonable, can complement each other's shortcomings

Calculation team

Students

Xia Shang Doctor
He LongYan Master

IHEP (5)

Ji Quan
Zhang JunSong
Yu jiebing
Fu JinYu
Pei YaTian
Hou ShaoJing

University

Hunan University
University of South China
Southwest Jiaotong University

Such a team is able to undertake CEPC design tasks

Design units

Zhejiang University

Manufacturing units

CITIC Heavy Industry

Design team

Future planning and visioning :

1. Allocate more mechanical engineers to join CEPC R&D as needed
2. Seeking cooperation units in special fields
3. Seek international cooperation

Summary and working plan

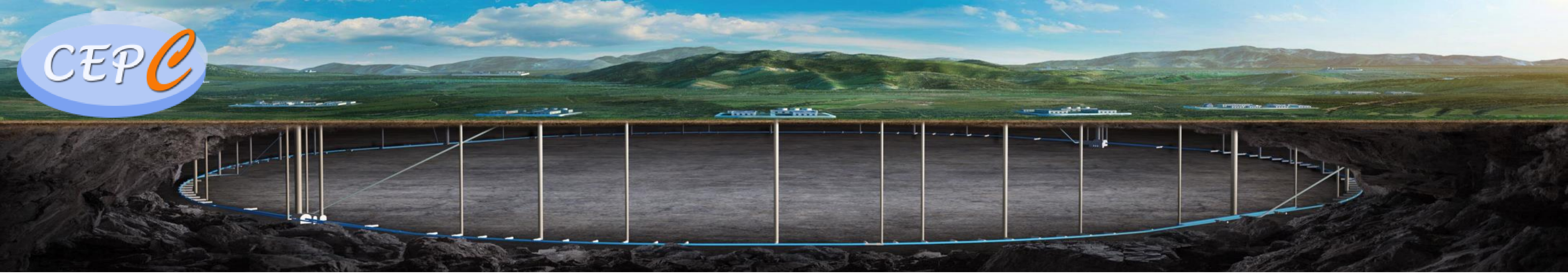
Summary

1. Supporting frame structure has been preliminary designed of each sub-detectors
2. The overall installation scheme for the detector has been basically completed

Summary and working plan

Working plan

1. Refine the installation scheme and connection design of sub detectors
2. Optimize the layout of the underground experimental hall and its auxiliary hall
3. Start planning the layout design of the ground hall



Thank you for your attention!

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences