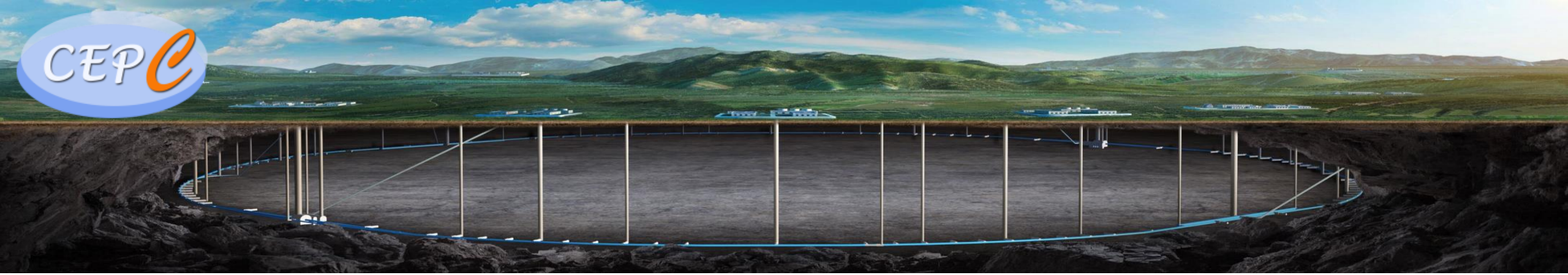

CEPC Detector Mechanical integration

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Content

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

Introduction

CEPC Detector Mechanical integration : (R&D content)

1. Draw and optimize a reasonable 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) the self supporting structure of the sub-detectors
3. Plan and optimize installation steps for each sub-detector

4. Plan and optimize configuration of the auxiliary equipment between the detectors and the experiment room layout and lifting capacity , etc. (Underground experiment room)
5. Others (underground auxiliary room , ground room)

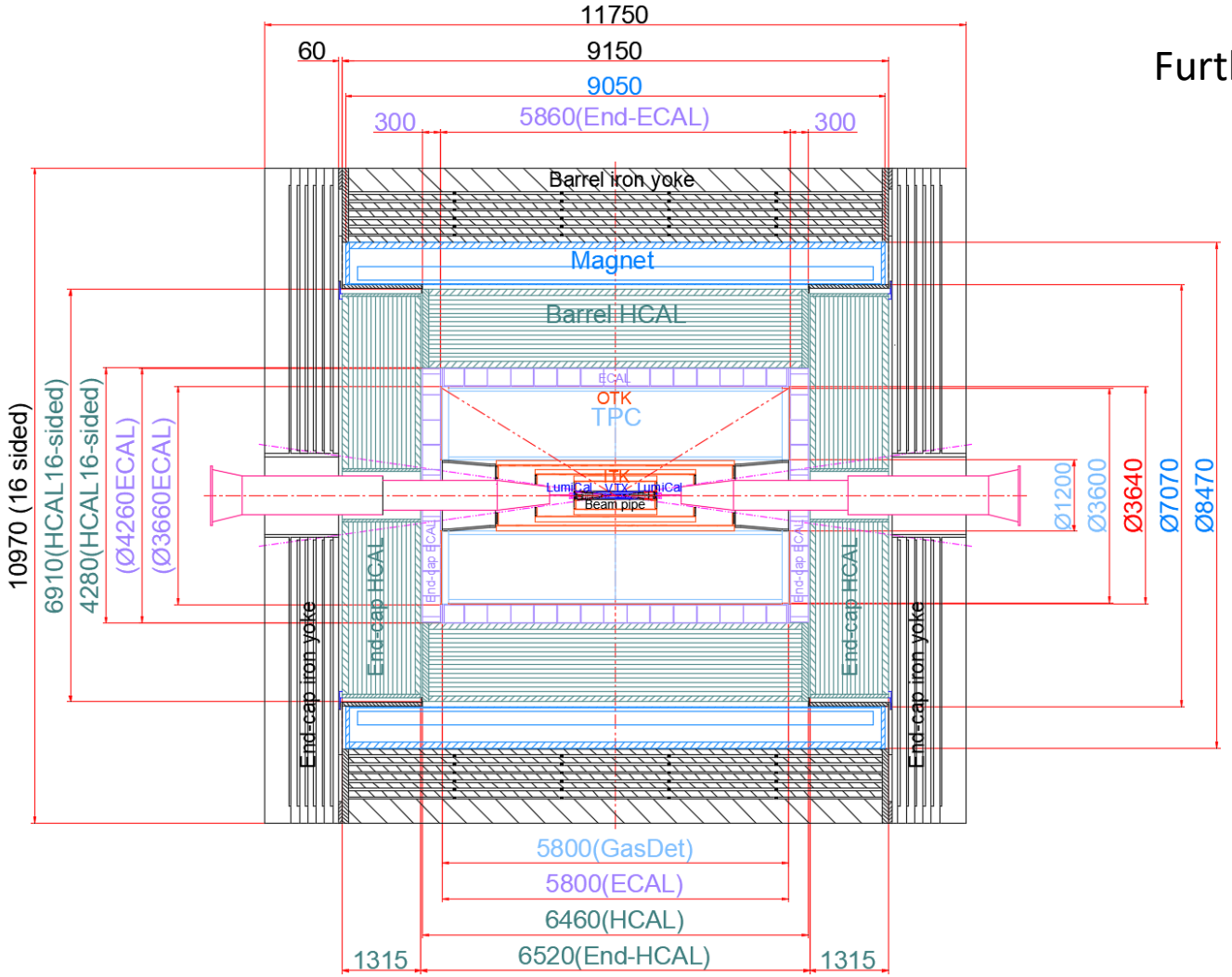
Overall Progress :

1. Original mechanical overall layout drawing
2. Original configuration drawing between the detectors and the underground experiment room

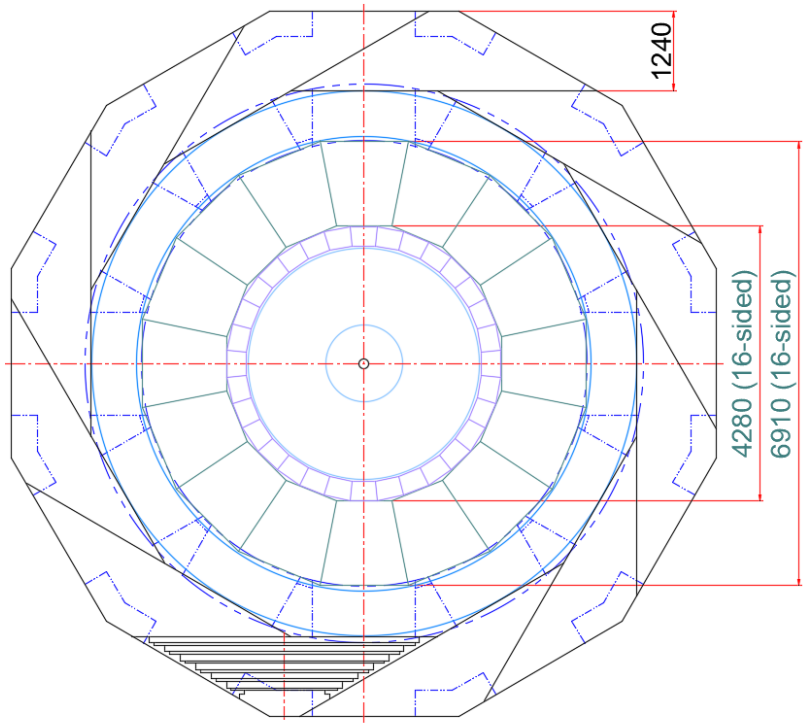
Key : Supporting frame structure is completed of each sub-detectors as soon as possible .

Introduction

Mechanical integration progress : Initial Size Distribution

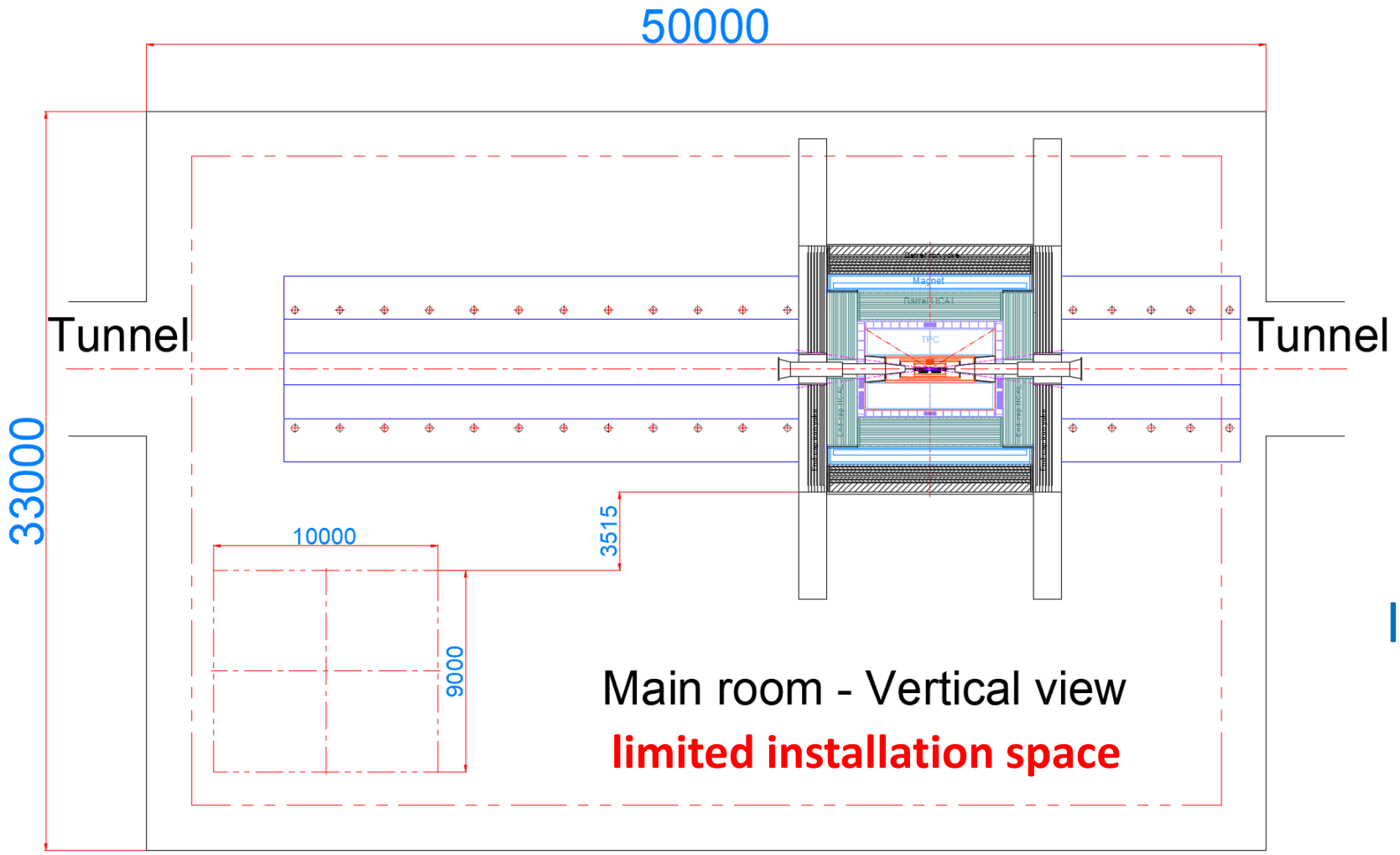


Further optimization and improvement are needed



Introduction

Mechanical integration progress : Configuration drawing between the detectors and the experiment room



Installation location :

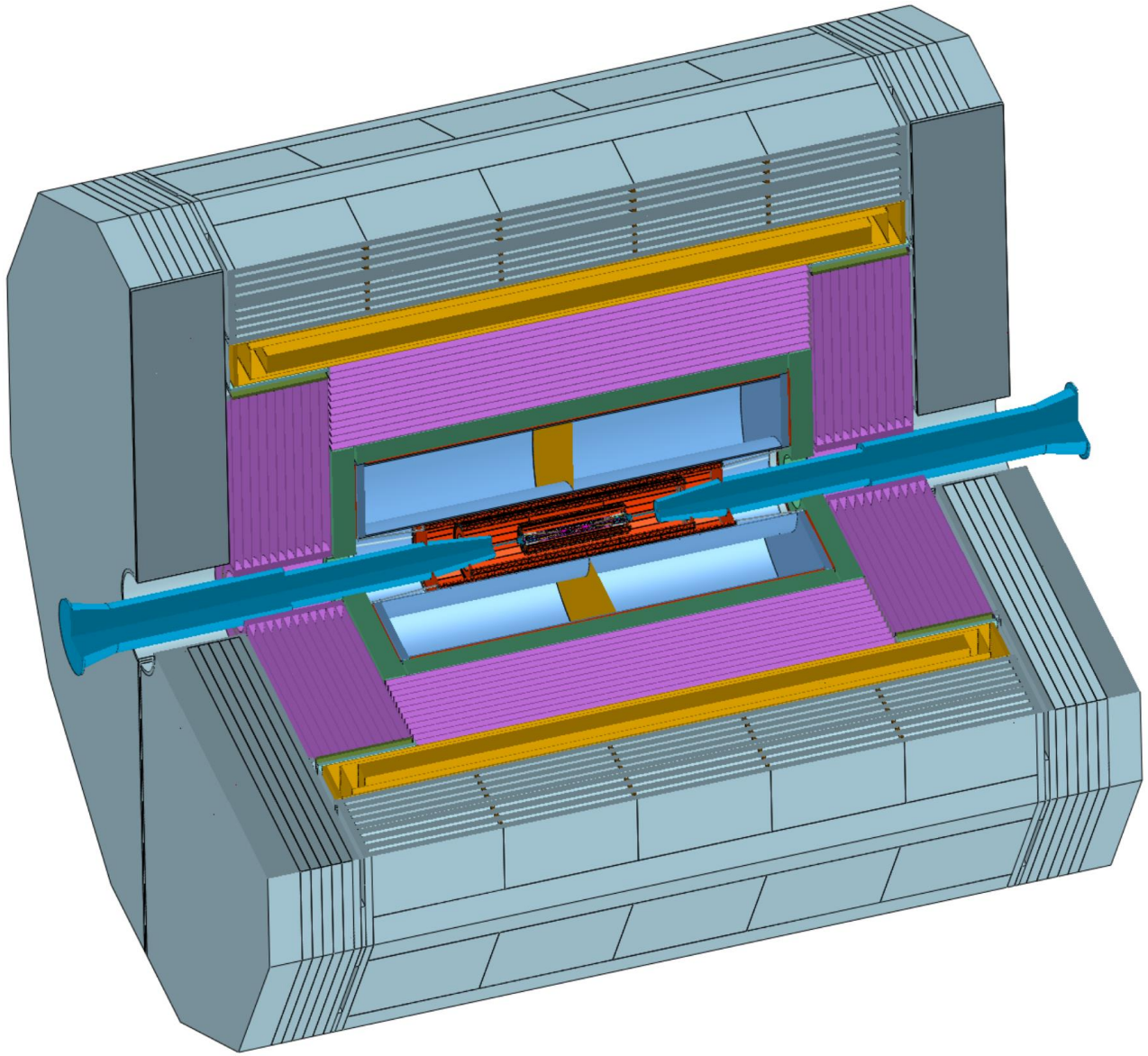
Collision point

Introduction

Total weight :

≈ 6000 t

Yoke : ≈ 3800 t
Magnet : ≈ 265 t
HCAL : ≈ 1780 t
……



Requirements

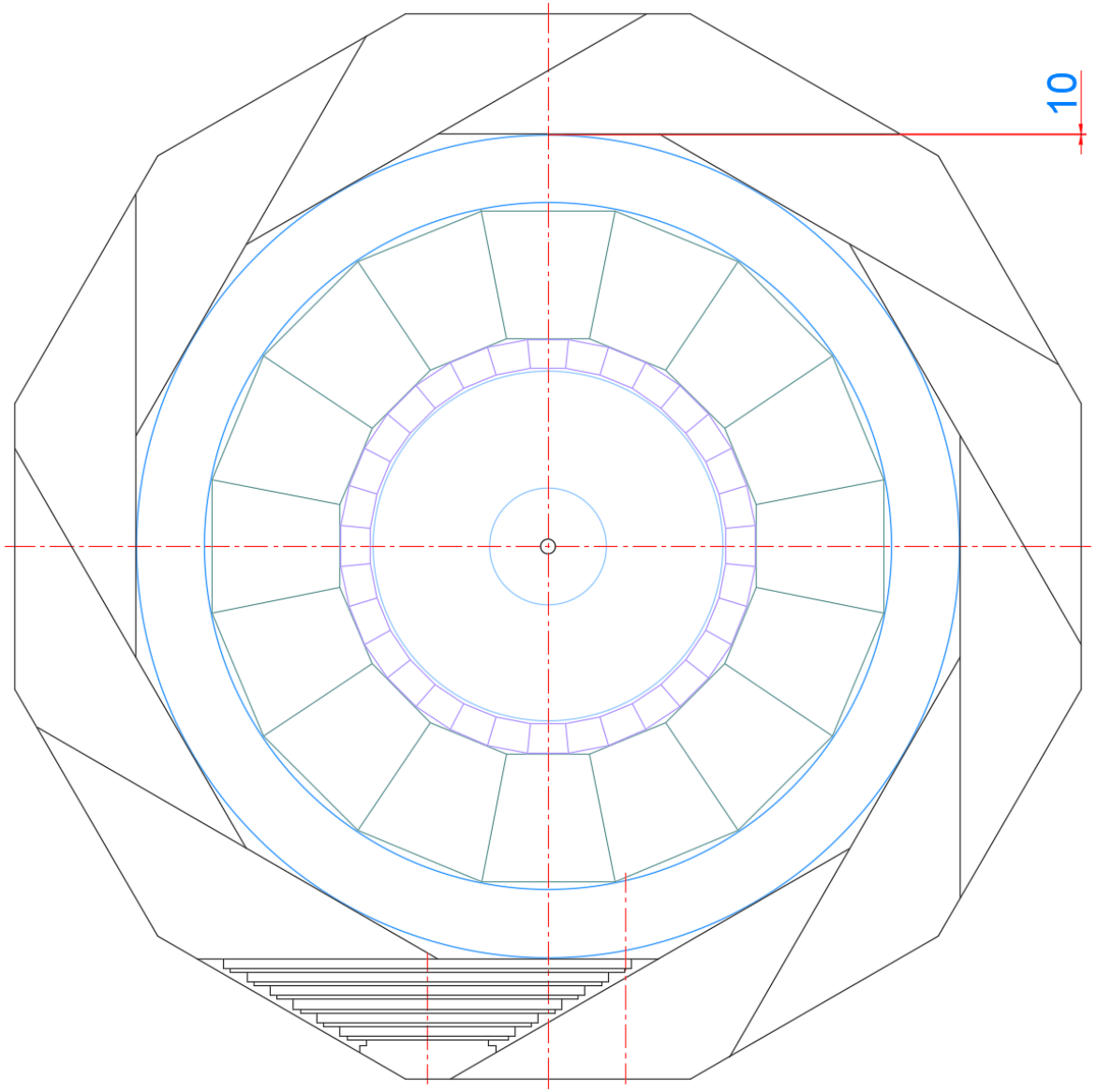
Minimum gap principle :

As small as possible

Gap between sub detectors :

Installation gap : ≤ 10mm

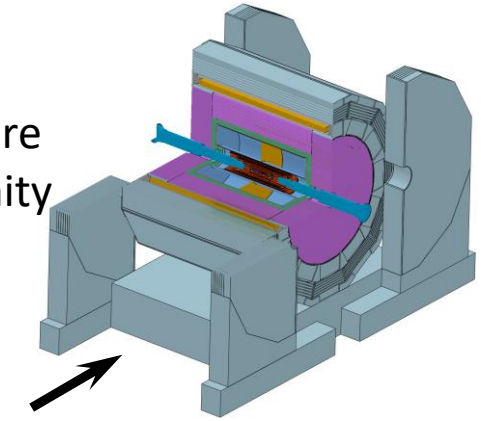
Note: Initial design parameters



Requirements

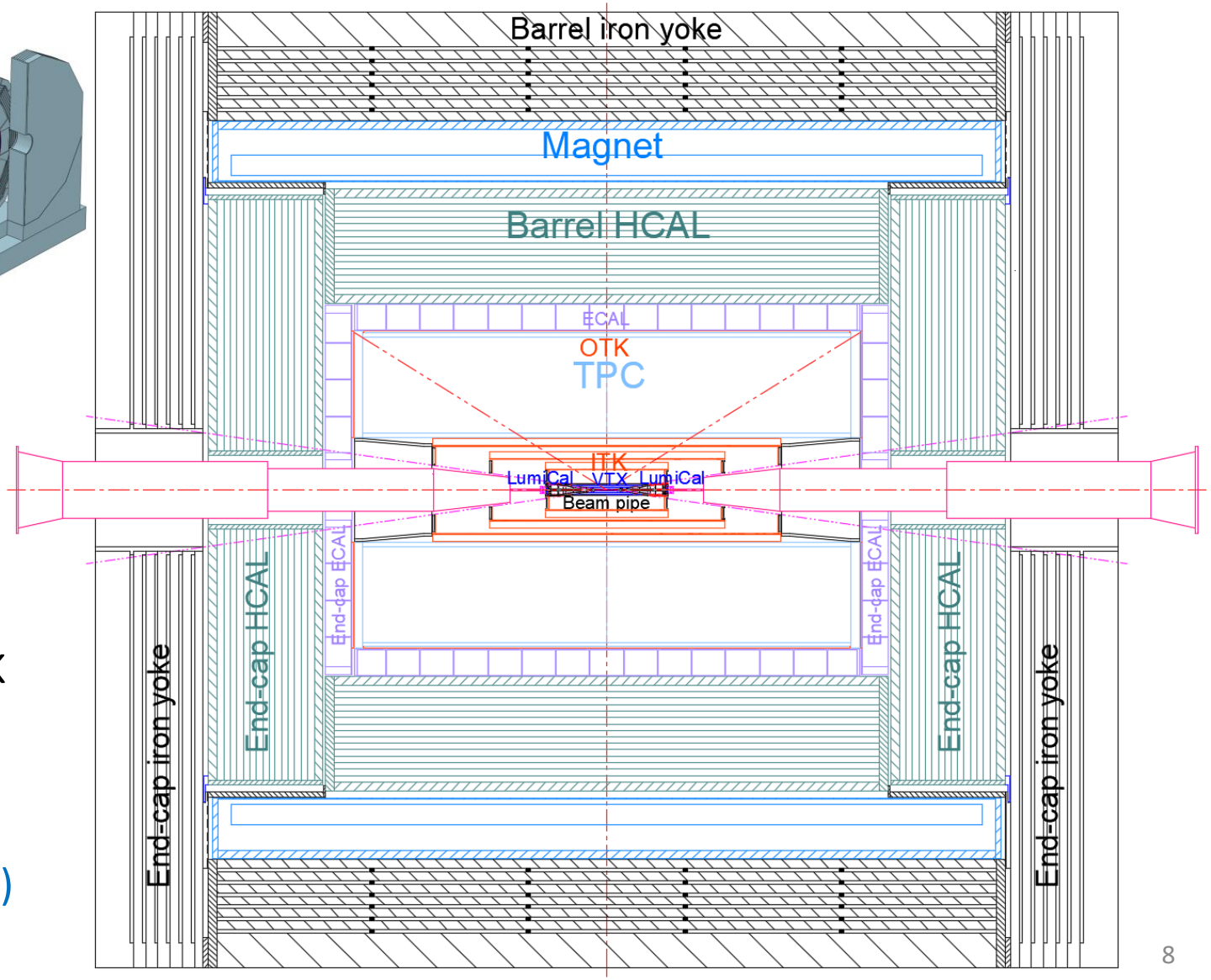
Connection design :

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

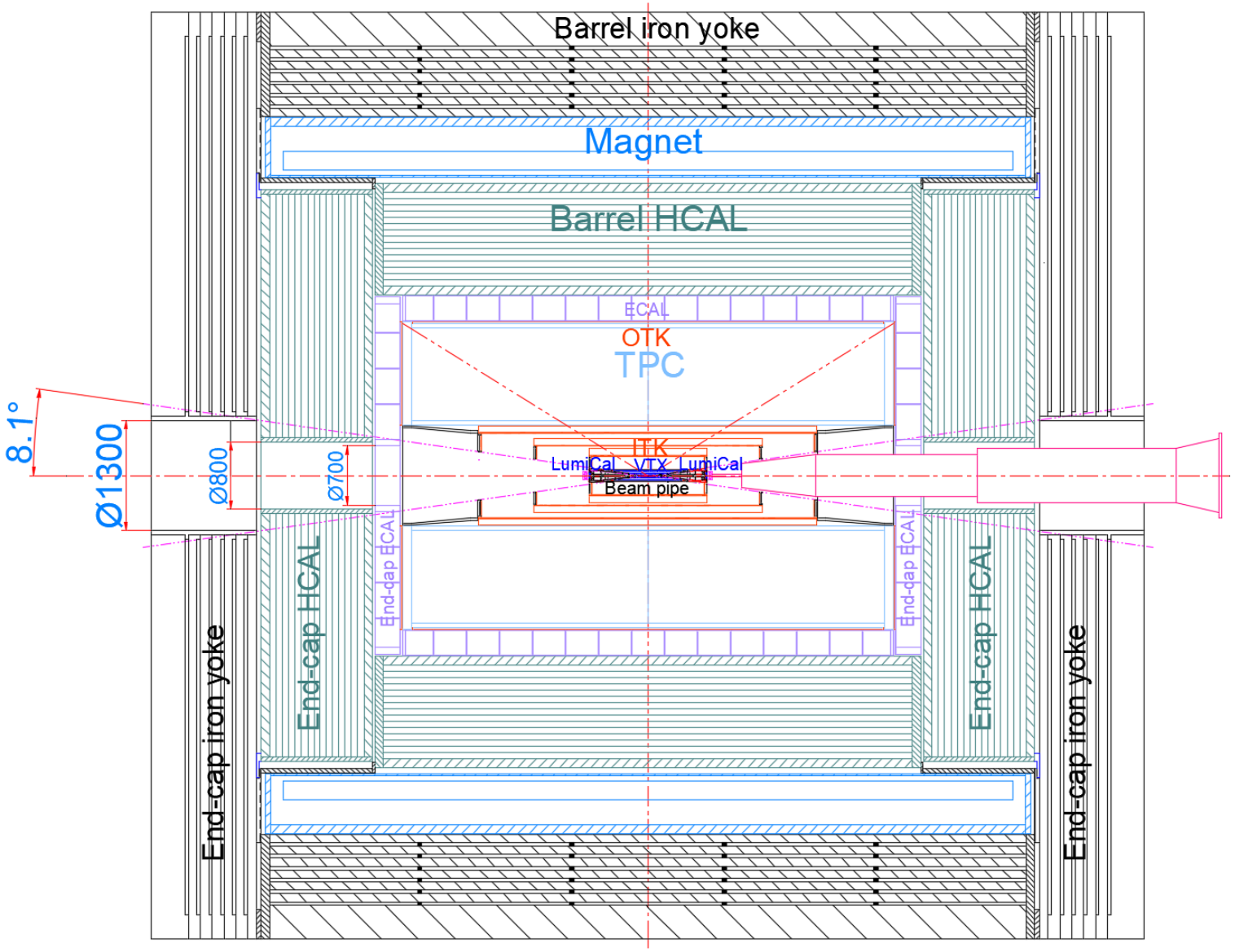
MDI boundary

Consists of 4 segments channels

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

(After ECAL)
ECAL : Ø700 mm
HCAL : Ø800 mm
Yoke : Ø1300 mm

Conical and stepped holes are reserved spaces for accelerators



Technical challenges

The CEPC detector is a non-standard design device with complex assembly, mainly reflected in the following aspects :

(From the perspective of mechanical design)

1. Extra large size and extra heavy weight (Dimensions > 10m, Weight > 6000 t)
2. Very small installation clearance (≤ 10mm)
3. High installation and collimation accuracy
3. Critical balance design between strength and rigidity(Meet the Low material budget)

How to design a large scientific device that reflects its charm, integrates culture and history, and presents a challenge to mechanical engineers

Key : No design experience

Comparison and selection of different schemes

The construction of CEPC has two characteristics :

long construction time and huge cost

The purpose of mechanical design optimization :

to reduce time and costs

Requirements for top-level installation design : (principle)

Complete the installation of all sub-detectors in the shortest time possible.

Design requirements for each sub-detector :

Minimal redundant installation tooling

Minimal installation steps

Key:

The design of each sub detector system must keep up with the overall requirements.

Taking yoke iron as an example (First installation component)

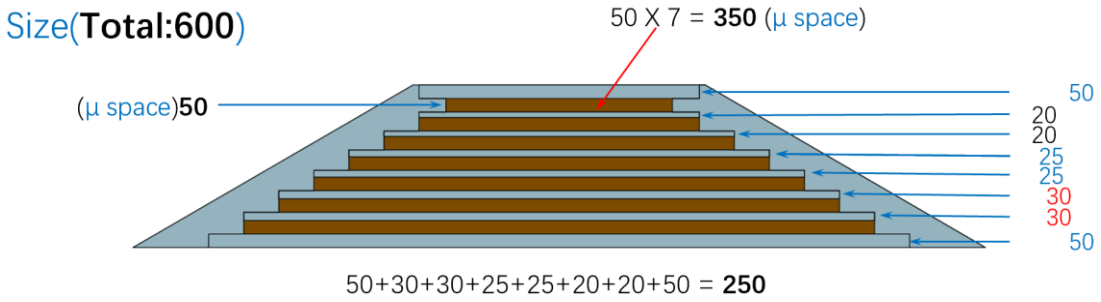
introduce its optimization process and concept design for quick installation

Comparison and selection of different schemes

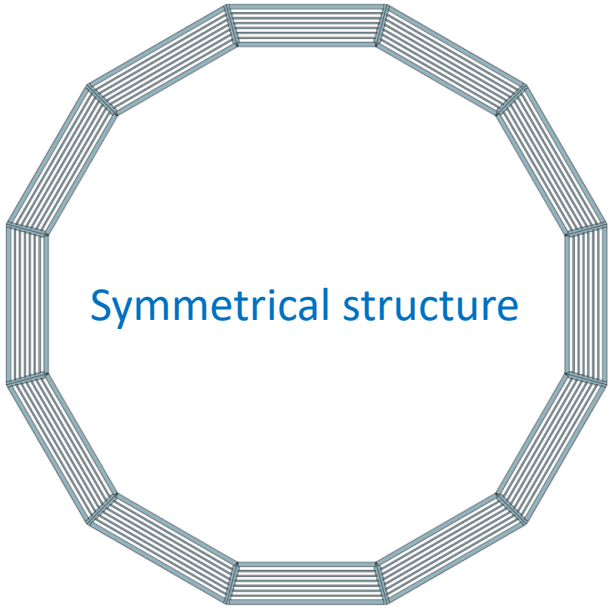
Comparison : Barrel Yoke

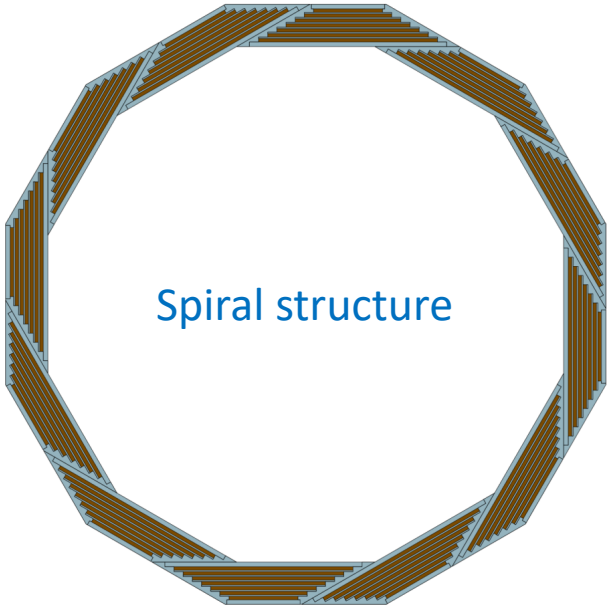
Tolerance requirements:

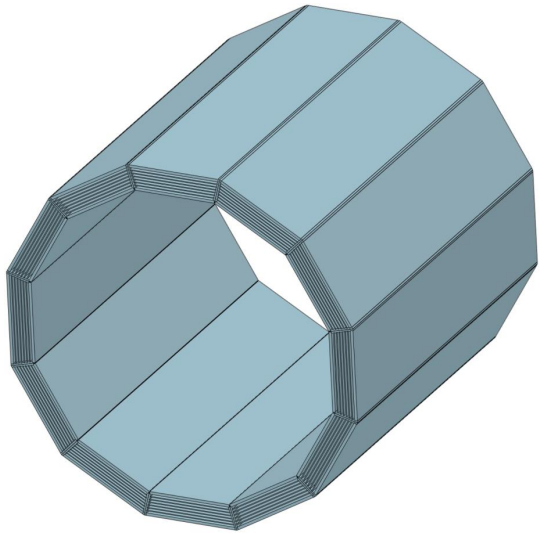
10970 ± 1

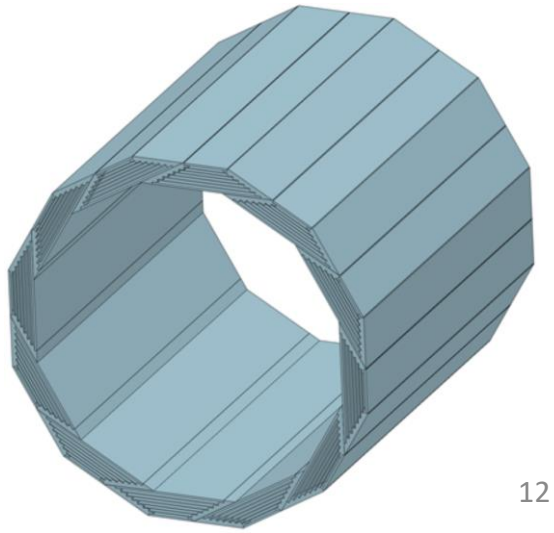


Baseline Parameters









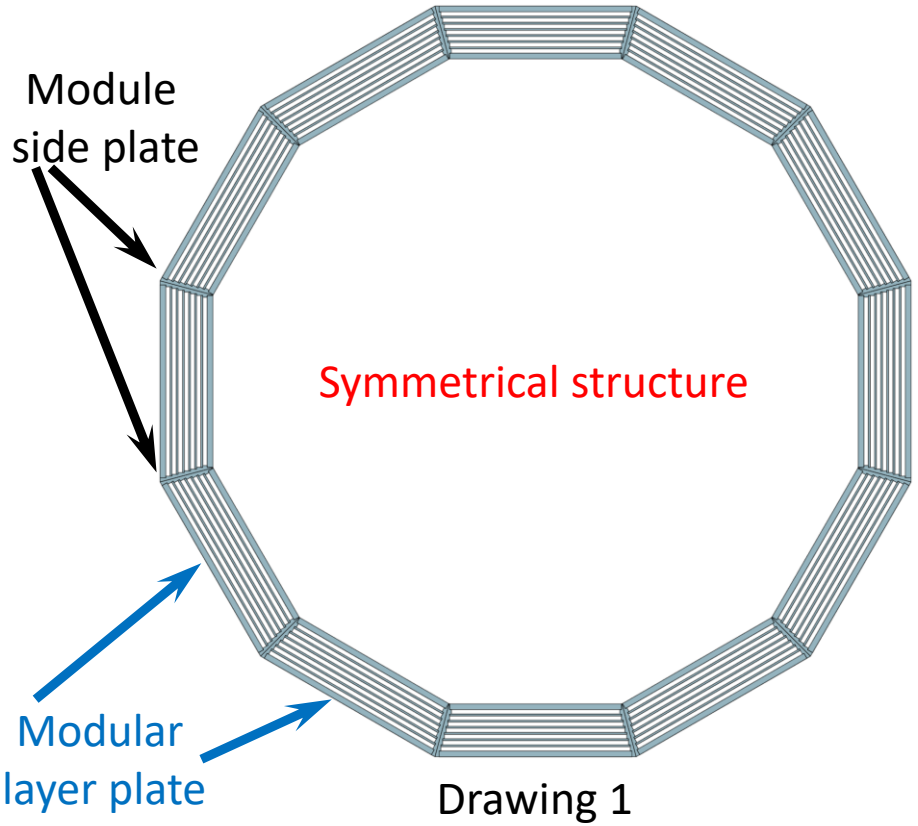
Comparison and selection of different schemes

The design optimization process of large scientific devices is a process of constant comparison and competition between the new options explored and the traditional ones

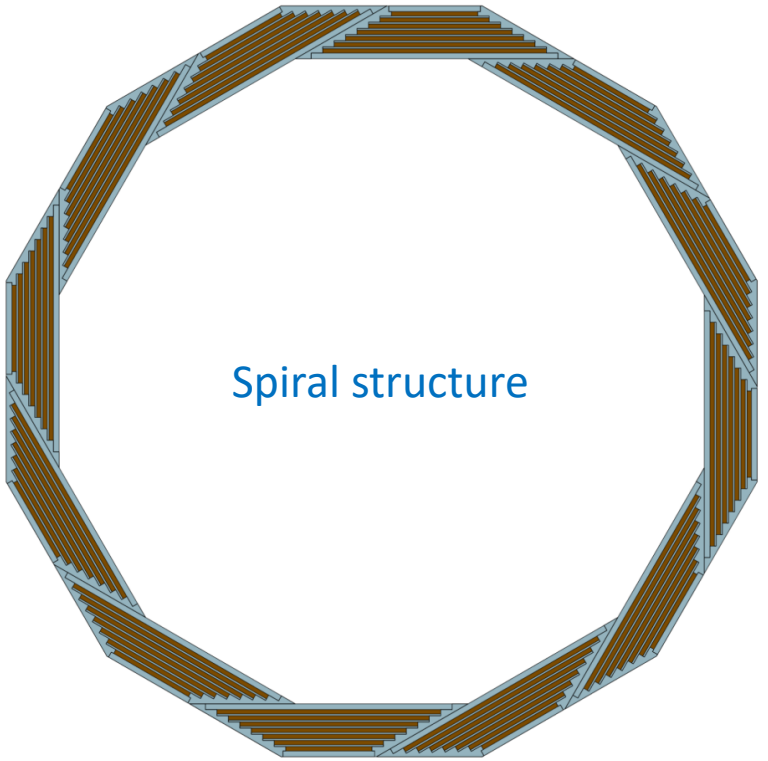
Structural design and optimization of yoke

From the perspective of Muon detector design :

Comparison:
Symmetrical (Old)
Spiral (New)



Drawing 1



Drawing 2

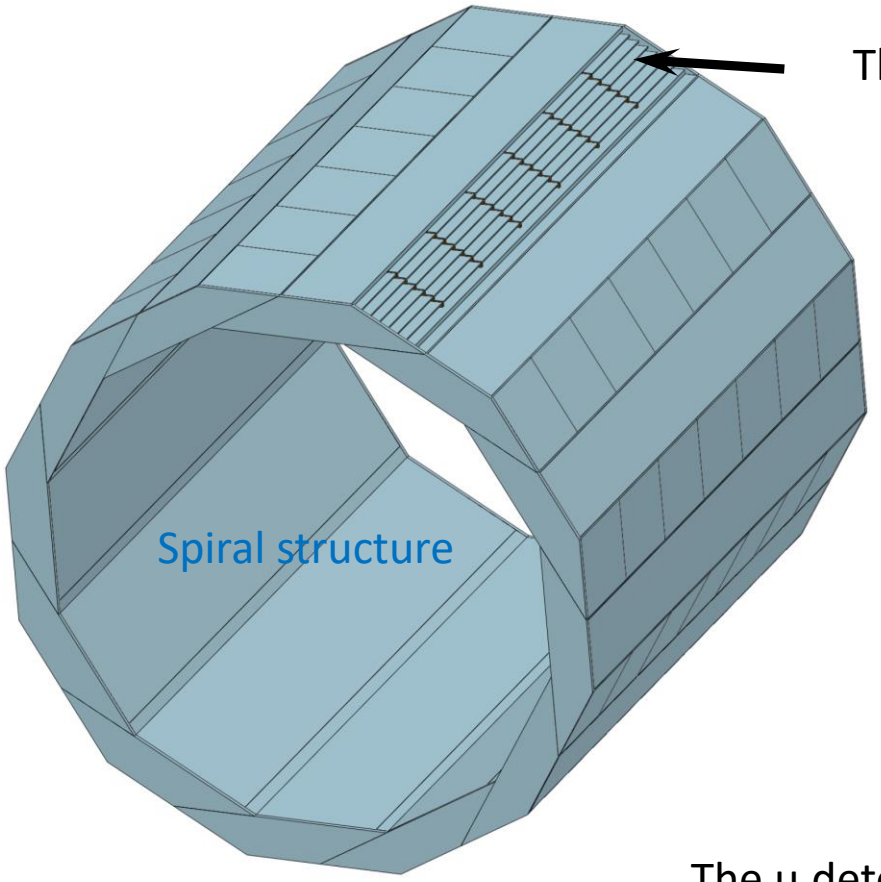
Drawing 1 :
Undetectable blind zones

Drawing 2 :
No detection blind zones

Comparison and selection of different schemes

Structural design and optimization of yoke

From the perspective of maintenance design :

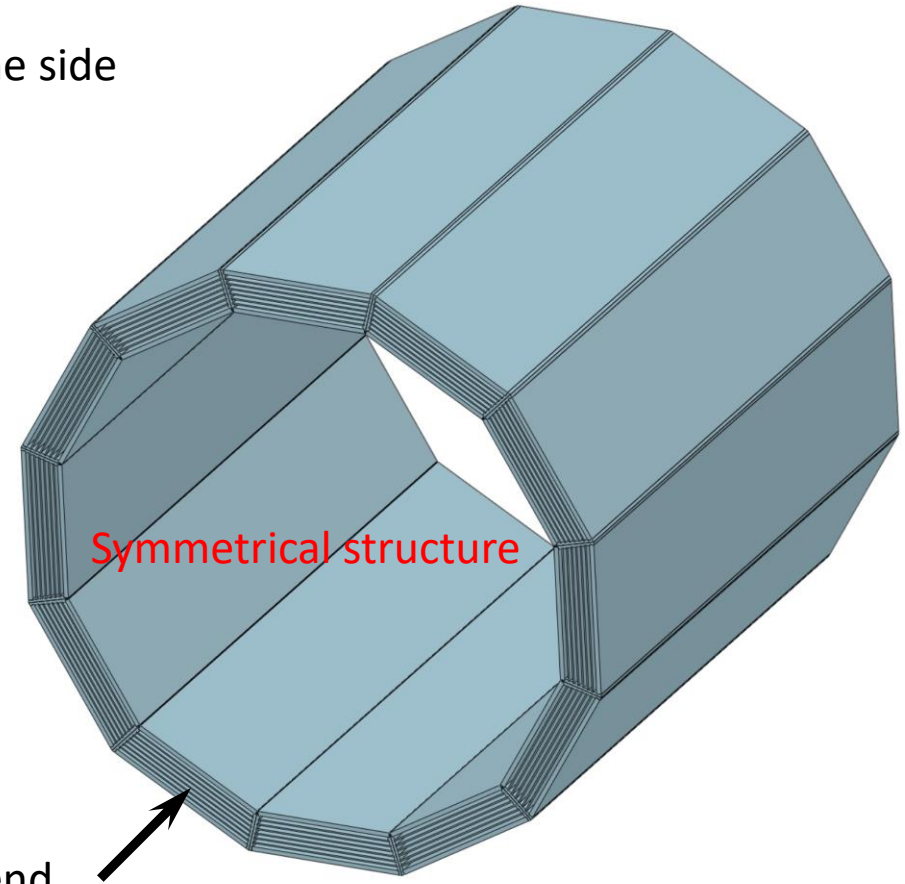


The μ detector can be installed from the side

Spiral structure :
Easy to maintain and replace

Comparison:
Symmetrical (Old)
Spiral (New)

Symmetrical structure :
Almost impossible to
maintain and replace

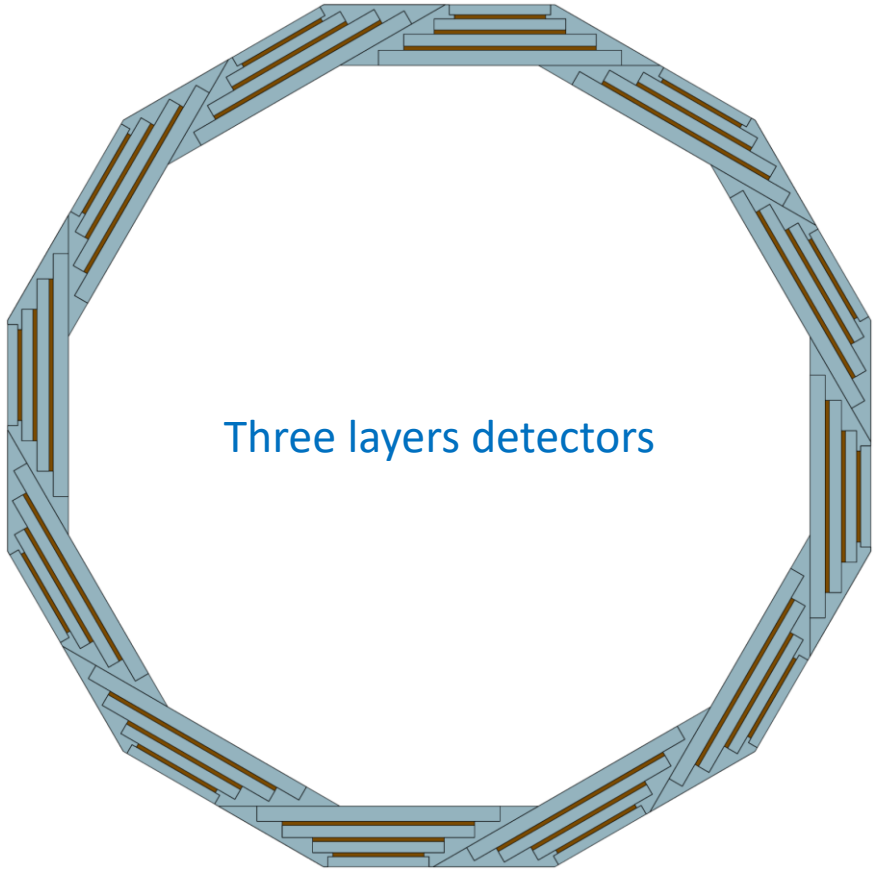


The μ detector can be installed from the both end

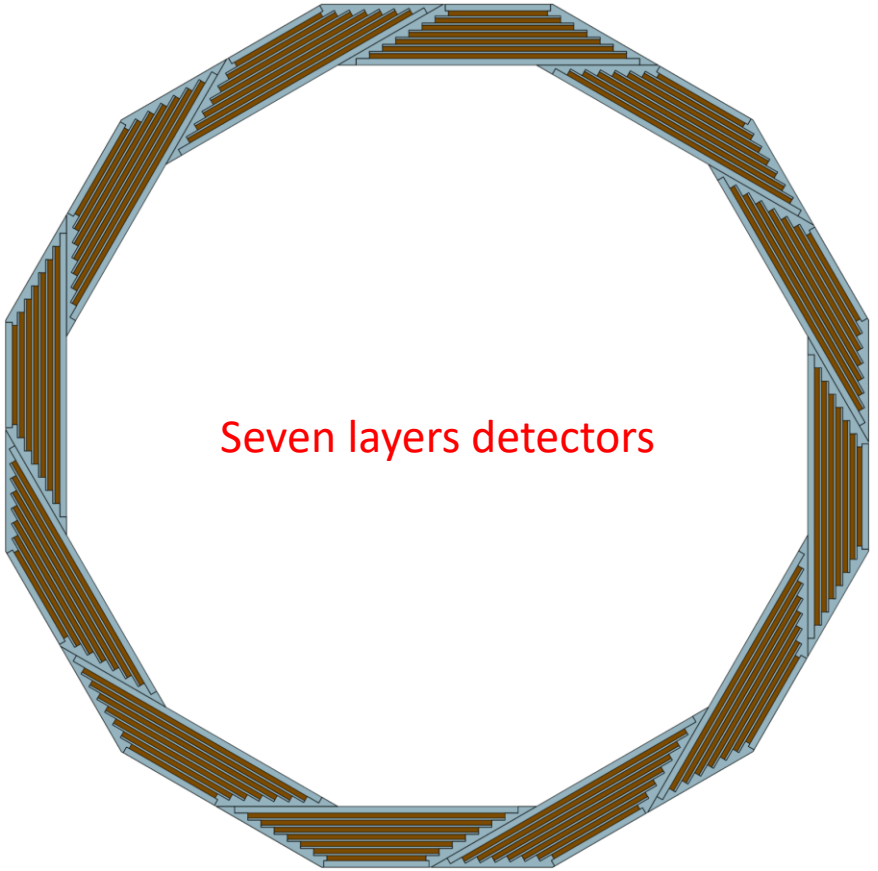
Comparison and selection of different schemes

Structural design and optimization of yoke

From the perspective of Muon detector and mechanical strength :



Drawing 1



Drawing 2

The more layers of the detector, the higher the detection accuracy and efficiency

Comparison:
Parameters

The more layers of the detector, the lower the mechanical strength and stiffness

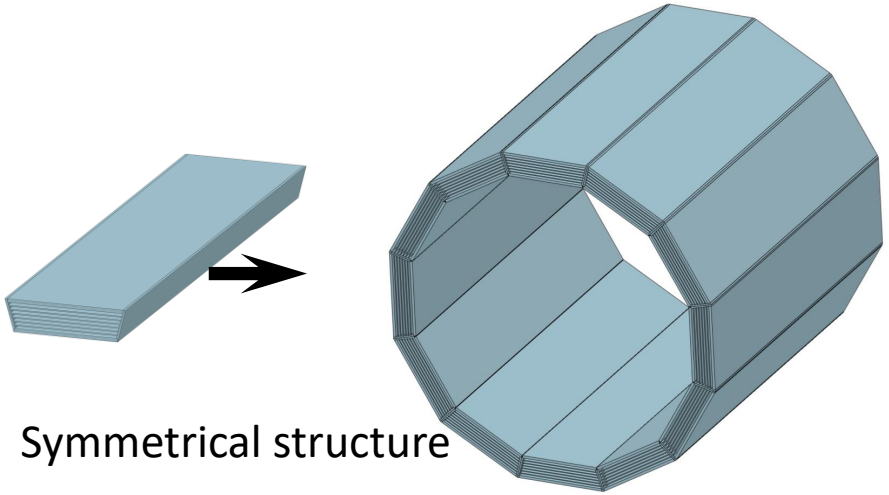
The purpose of optimization :
Seeking the optimal structure and parameters

Comparison and selection of different schemes

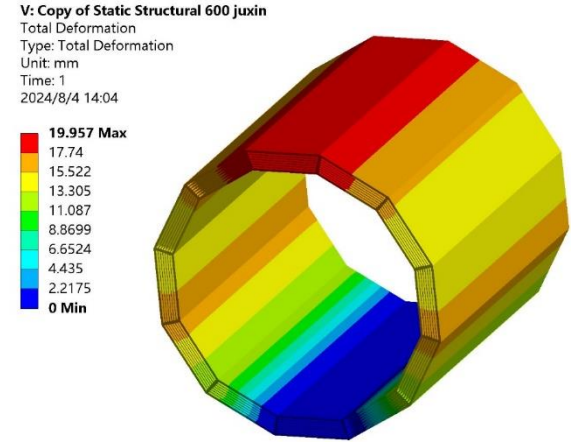
Structural design and optimization of yoke

From the perspective of structural deformation :

The spiral structure is more resistant to self-weight deformation



Symmetrical structure



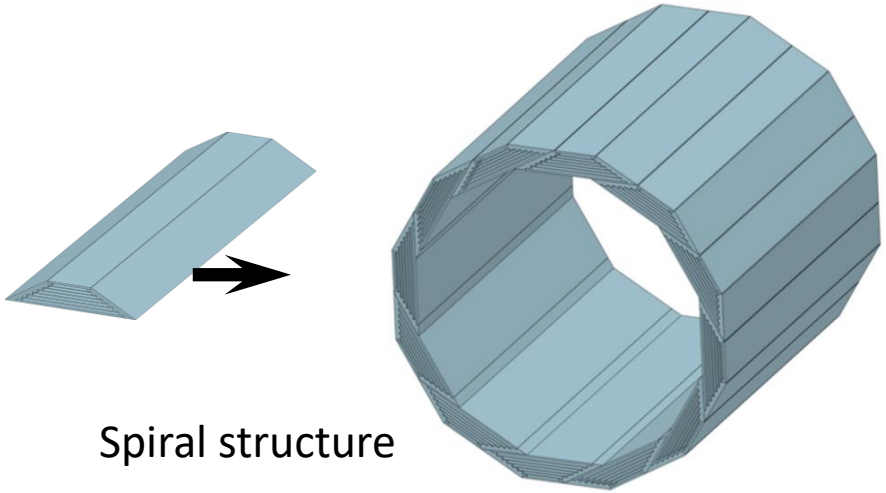
Self-weight deformation :

≈ 20.00 mm

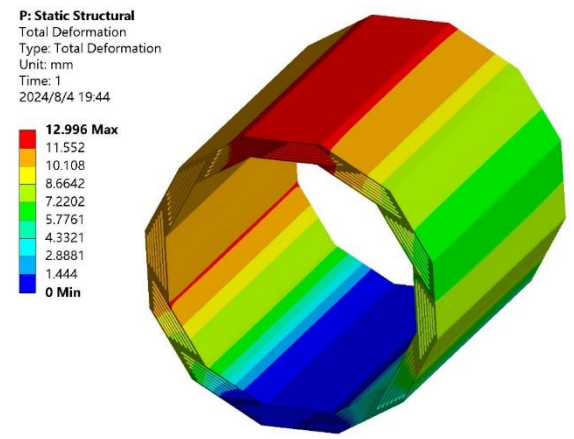
Comparison:

Symmetrical (Old)

Spiral (New)



Spiral structure



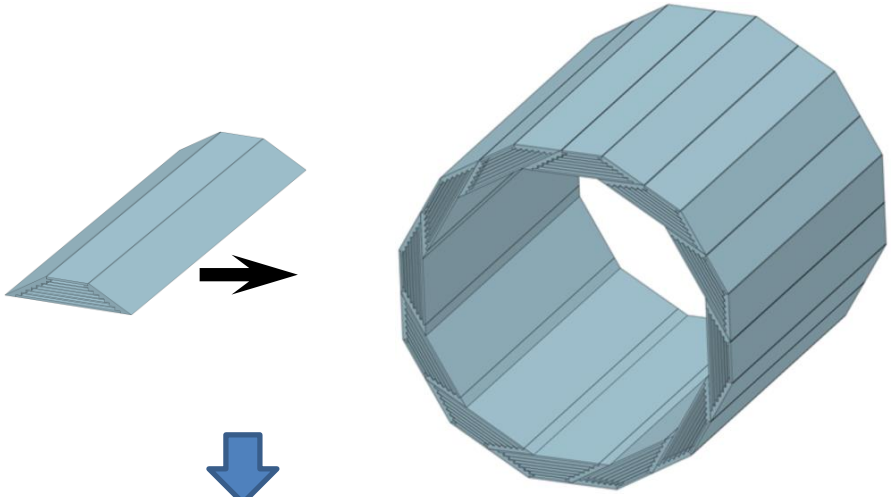
Self-weight deformation :

≈ 13.00 mm

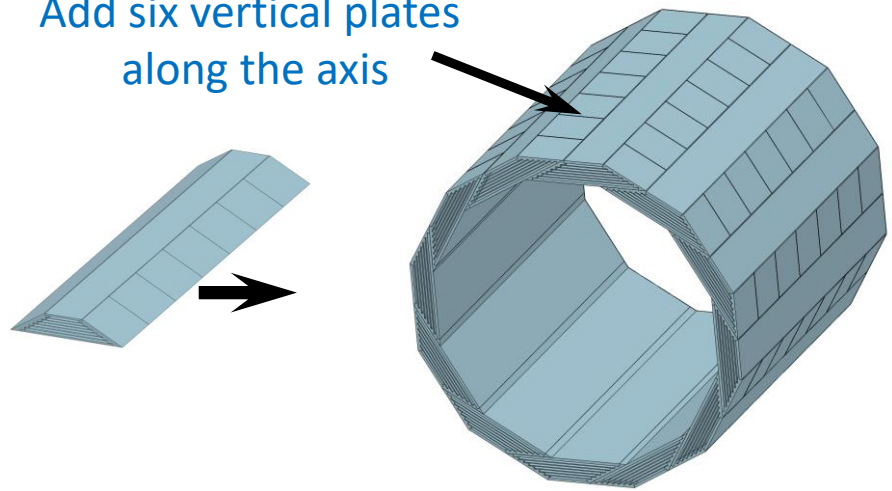
Comparison and selection of different schemes

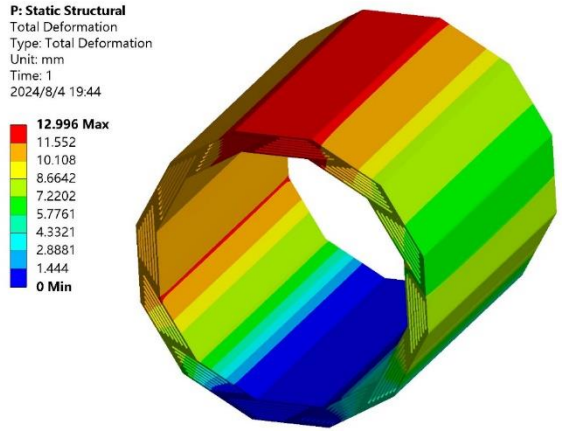
Structural design and optimization of yoke

From the perspective of structural deformation : (Spiral)



Add six vertical plates along the axis



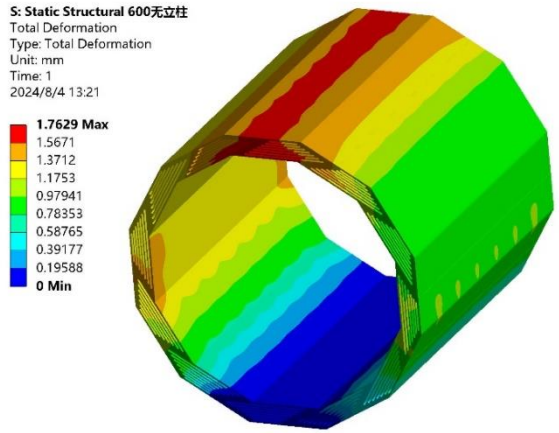


Self-weight deformation :

≈ 13.00 mm

Comparison:

Parameters



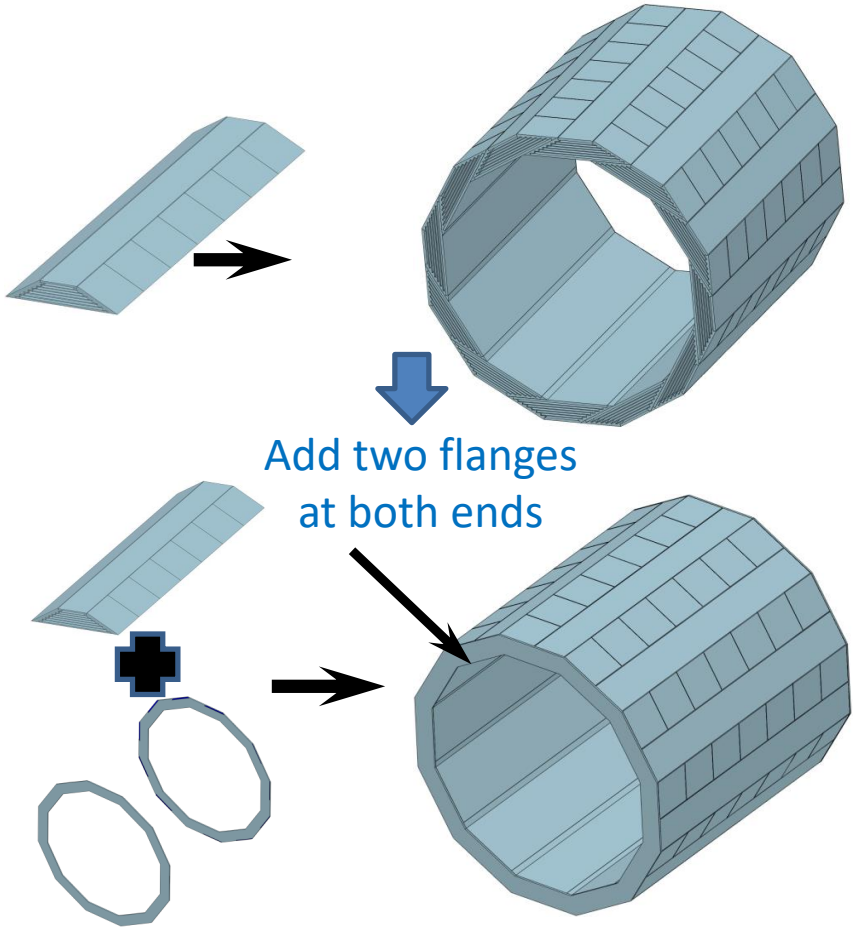
Self-weight deformation :

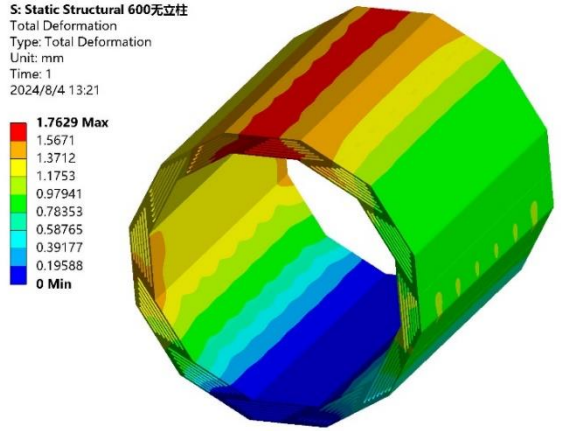
≈ 1.76 mm

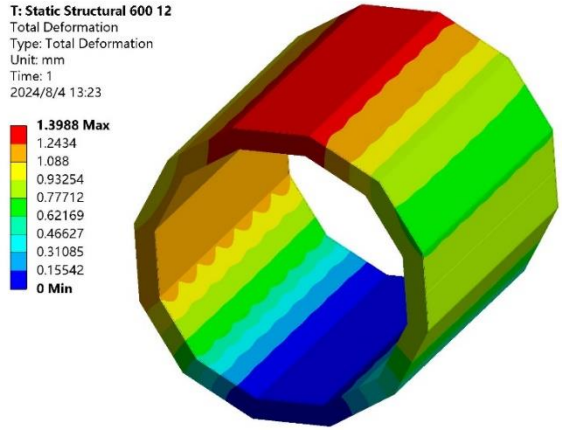
Comparison and selection of different schemes

Structural design and optimization of yoke

From the perspective of structural deformation : (Spiral)







Self-weight deformation :

≈ 1.76 mm

Comparison:

With flanges

Without flanges

Self-weight deformation :

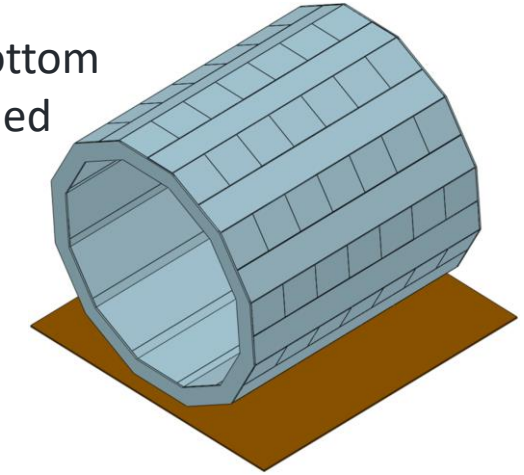
≈ 1.40 mm

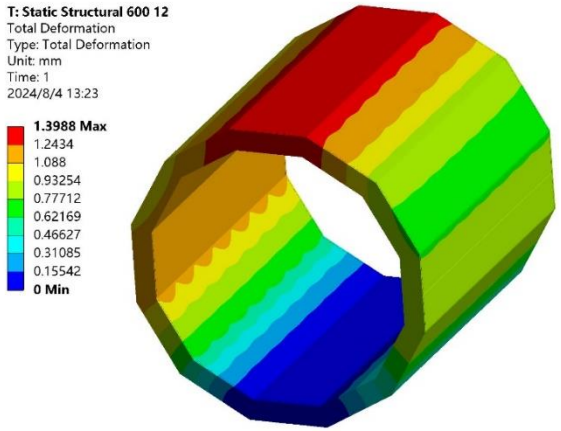
Comparison and selection of different schemes

Structural design and optimization of yoke

From the perspective of structural deformation : (Spiral)

The flange bottom is suspended





Self-weight deformation :

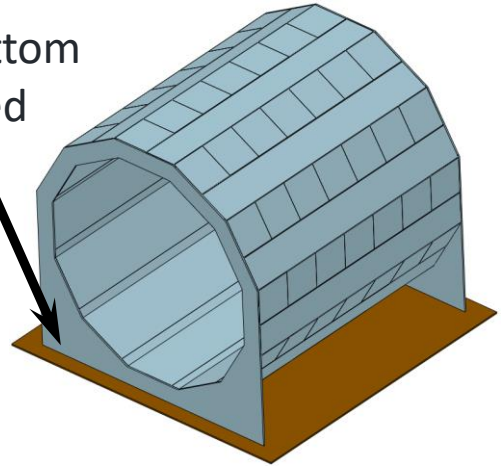
≈ 1.40 mm

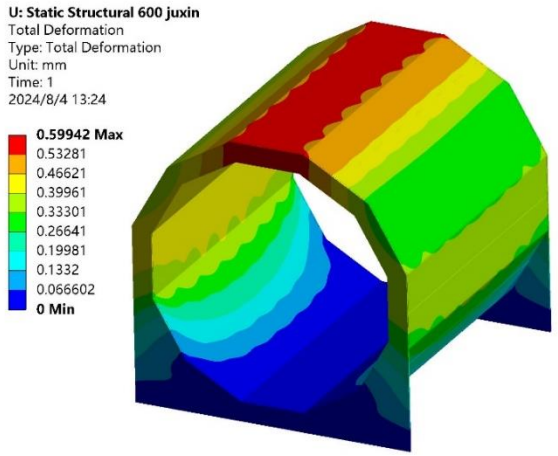
Comparison:

Suspended

Supported

The flange bottom is supported





Self-weight deformation :

≈ 0.60 mm

Meet : < 1

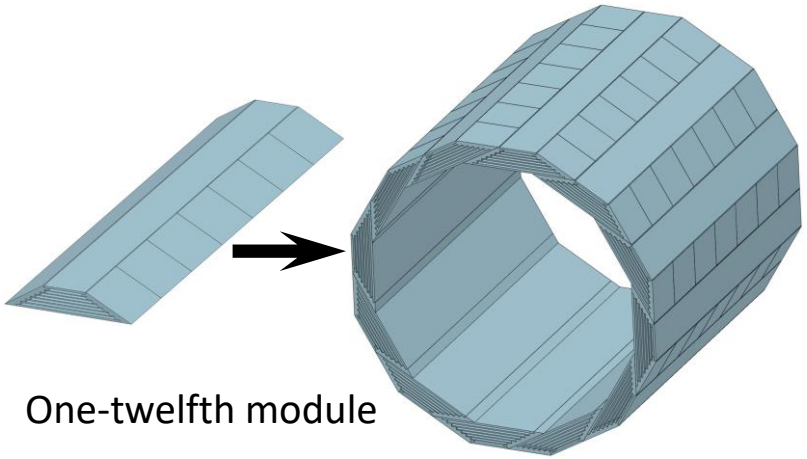
Comparison and selection of different schemes

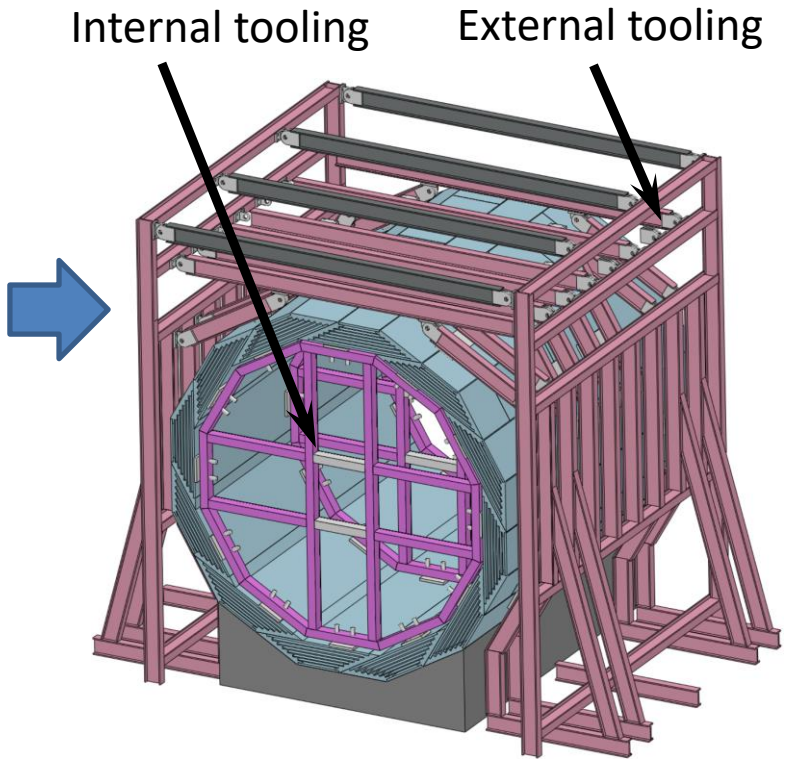
Structural design and optimization of yoke

From the perspective of installation design :

Key : Different structural designs result in different installation designs

Scheme 1 : Conventional structural





Shortcomings :

1. Installation steps are complex
   Assembly must be possible with the help of the auxiliary tooling
2. Every step of the installation requires collimation
3. Installation process requires more space and time
4. **Uncontrollable installing accuracy**

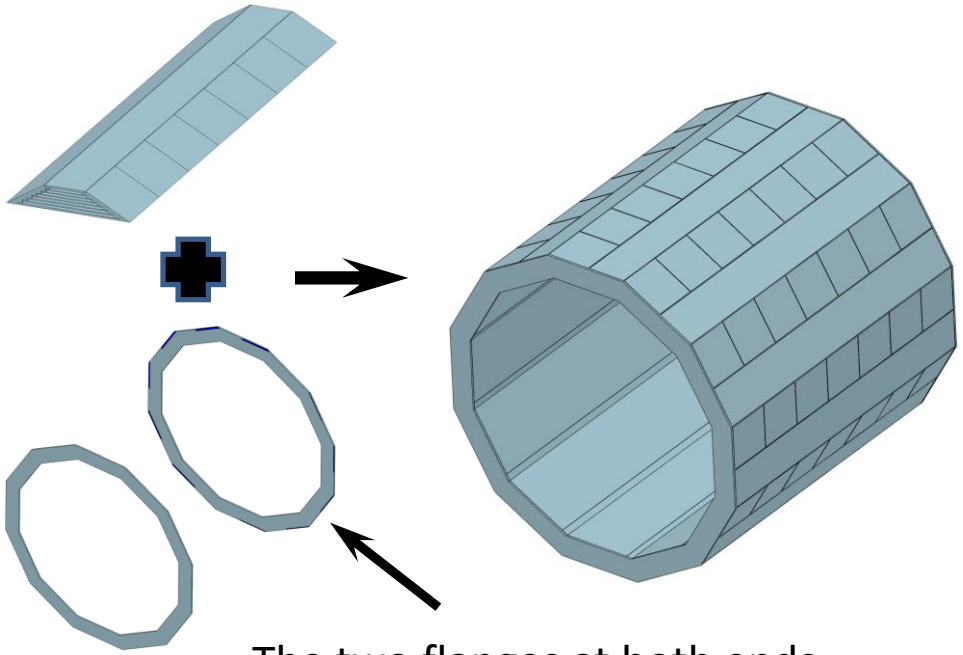
Comparison and selection of different schemes

Structural design and optimization of yoke

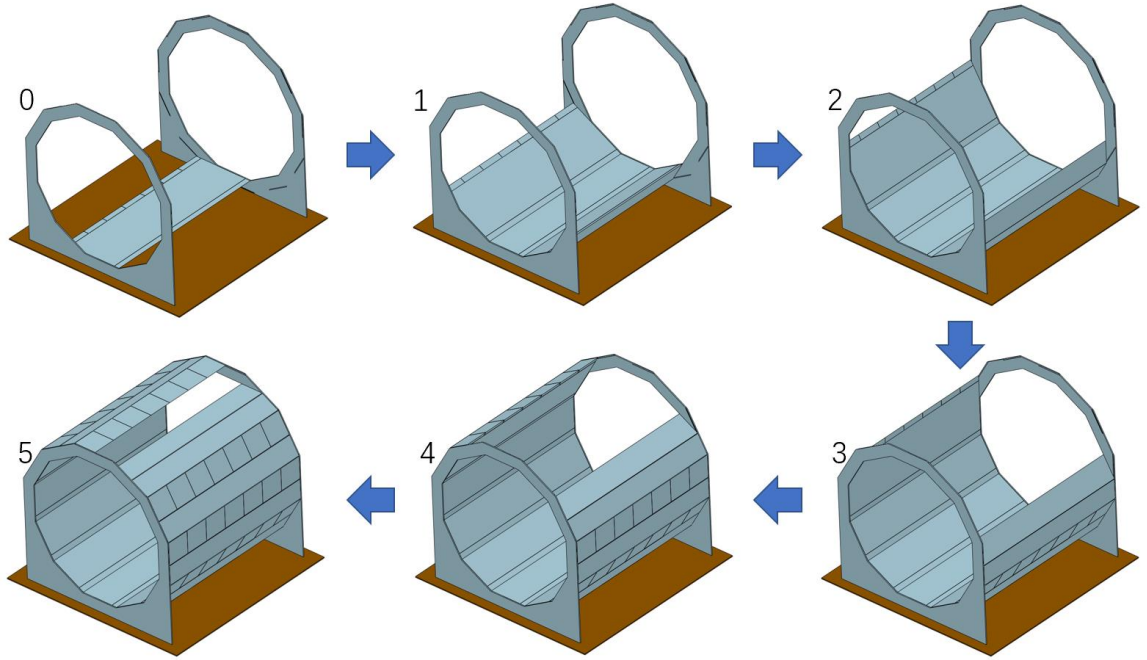
From the perspective of installation design :

Key : Different structural designs result in different installation designs

Scheme 2 : Self supporting structural



The two flanges at both ends are the installation tooling



The whole installation process, without any additional auxiliary tools.

Comparison and selection of different schemes

Selection : (?) --- It's too early to make a final decision

Recommendation: Optimize the spiral structure

1. Continue to optimize the mechanical design of the yoke based on :
   1.1 The requirements of tracking detectors and electronics
   1.2 Technical feasibility of processing, transportation, and assembly

2. Optimize the configuration of lifting fixtures and lifting equipment based on the idea of quick installation

3. Suggestion:
   The mechanical design of each sub detector must have a similar process of comparison and optimization

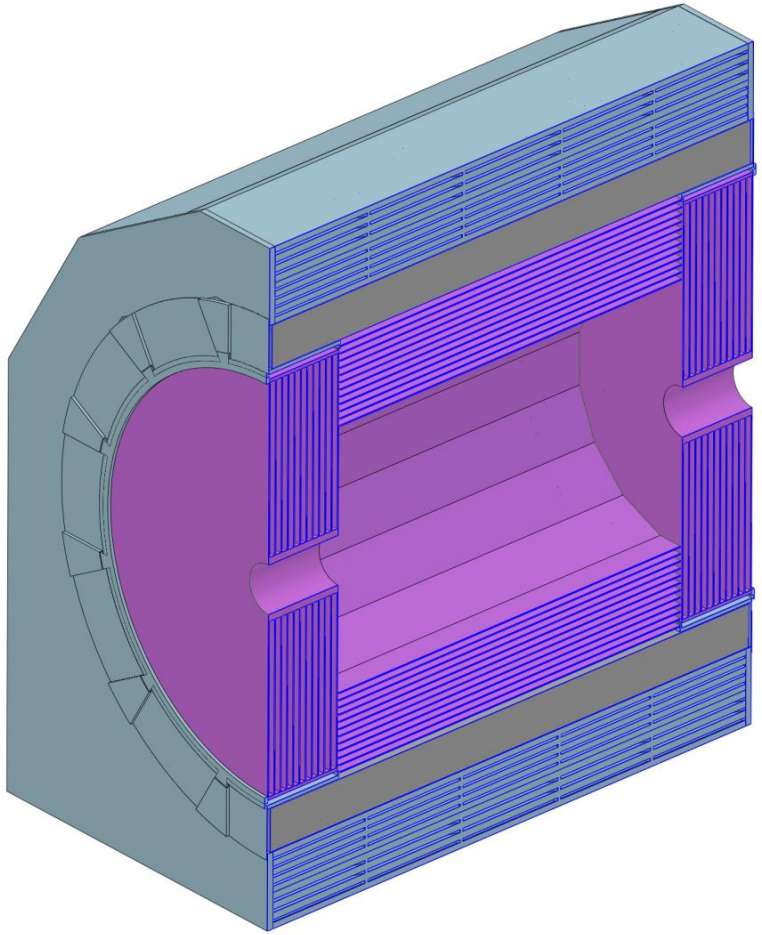
Overall installation concept design

Overall installation requirements:

1. Overall reliability and safety assessment (FEA --- stress and deformation)
2. Overall installation steps
3. Installation sequence
4. Considerations for integral and separate lifting of components

Overall installation concept design

Overall reliability and safety assessment



Key :

Deformation and stress of the Yoke and the connection structure

(Yes ? No)

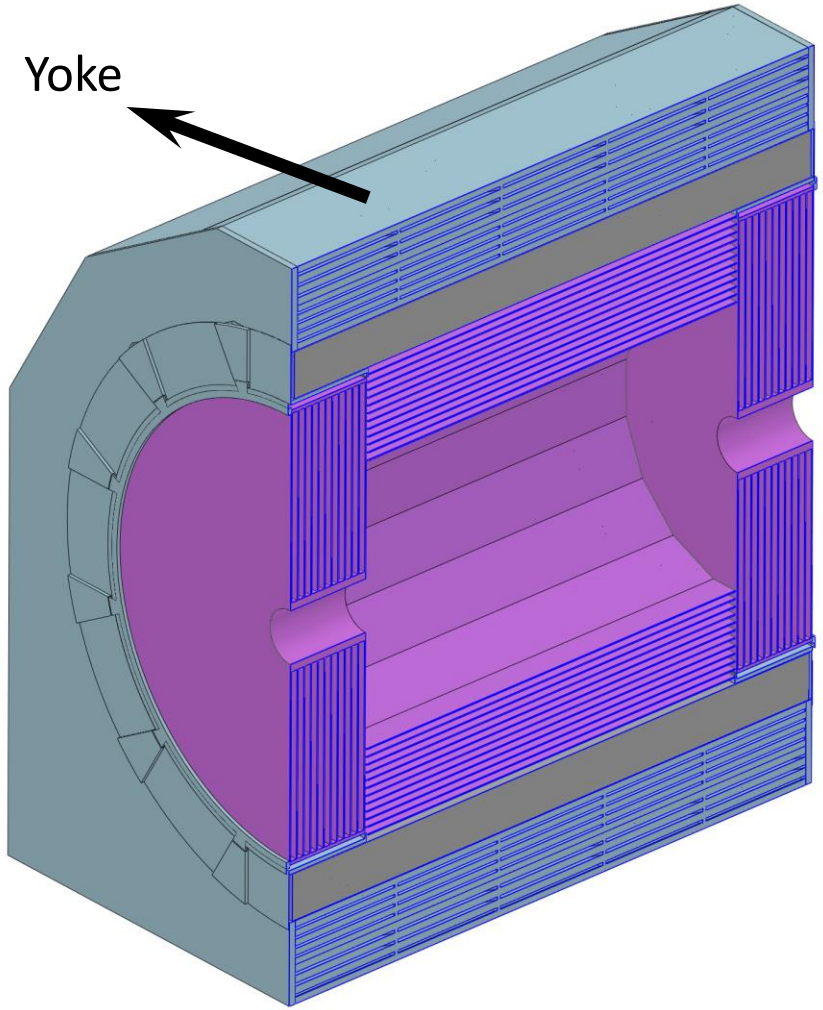
As shown in the left figure:

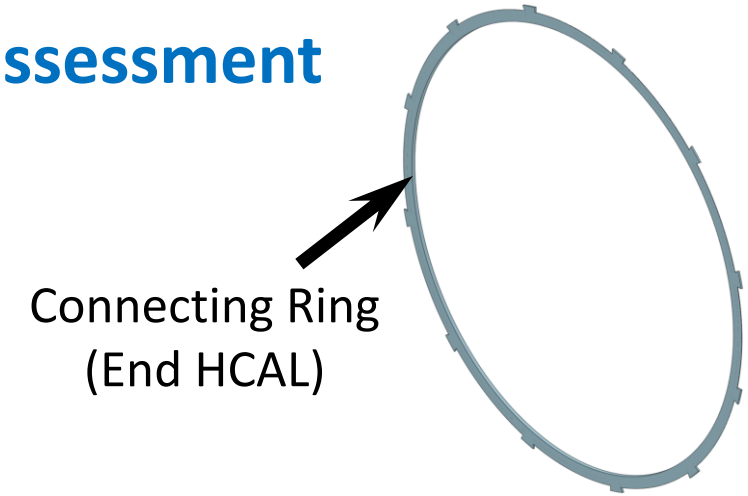
1. Preliminary design of the connection structure between the yoke, magnet and HCAL
2. Other lighter components are ignored

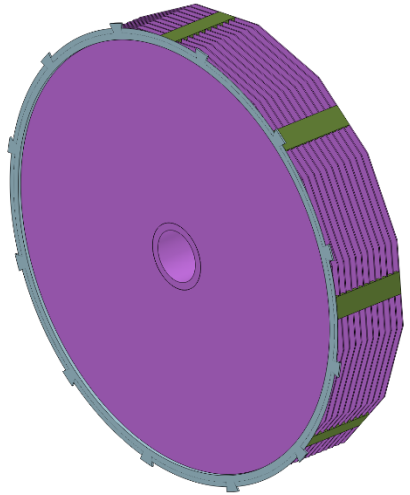
   These components do not affect the calculation results and overall assessment

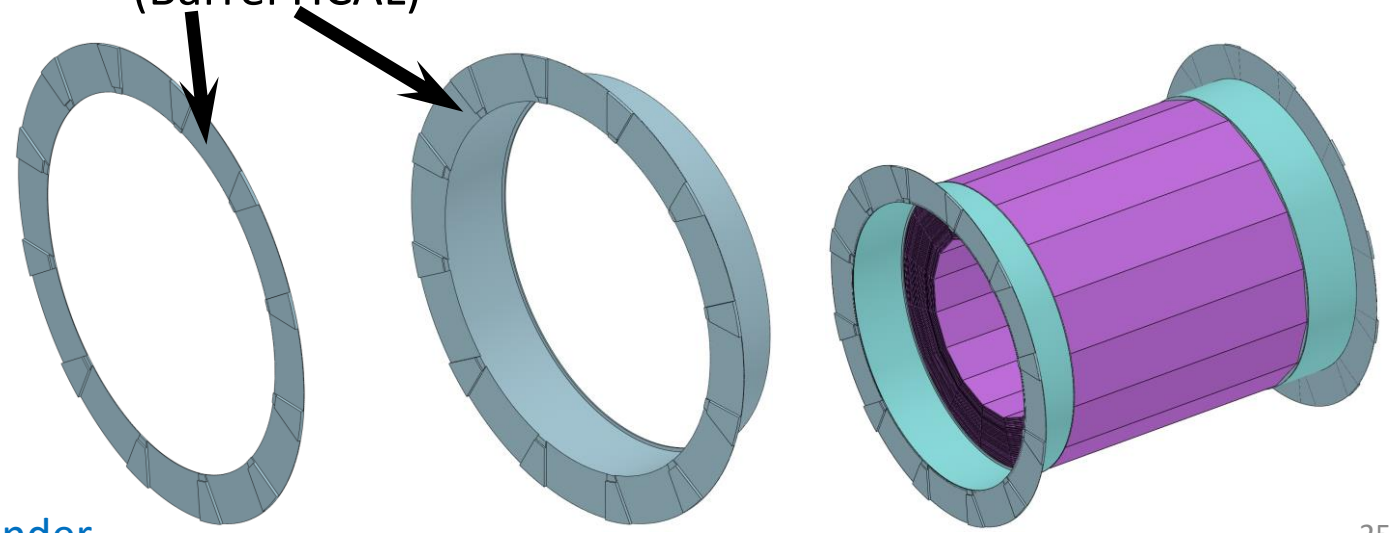
Overall installation concept design

Overall reliability and safety assessment





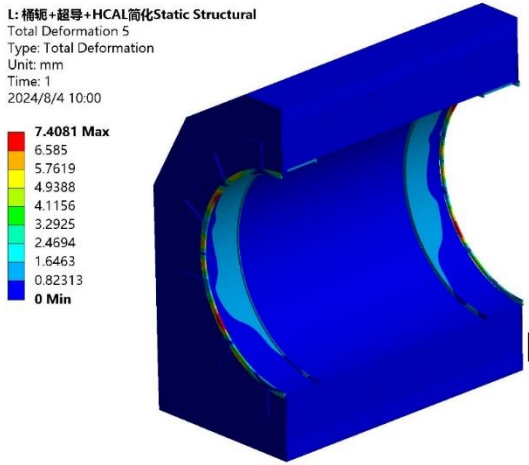


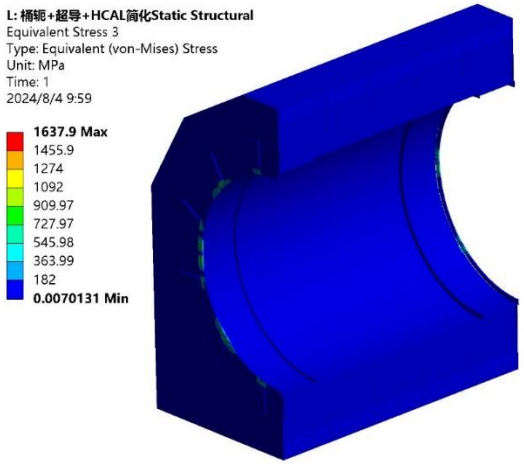


Check Yoke, Ring, Flange, Cylinder

Overall installation concept design

Overall reliability and safety assessment

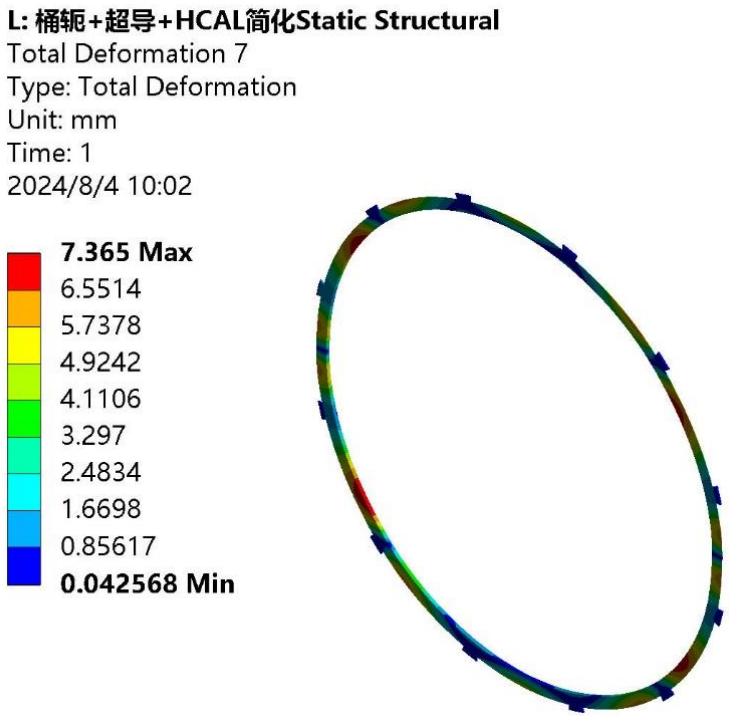




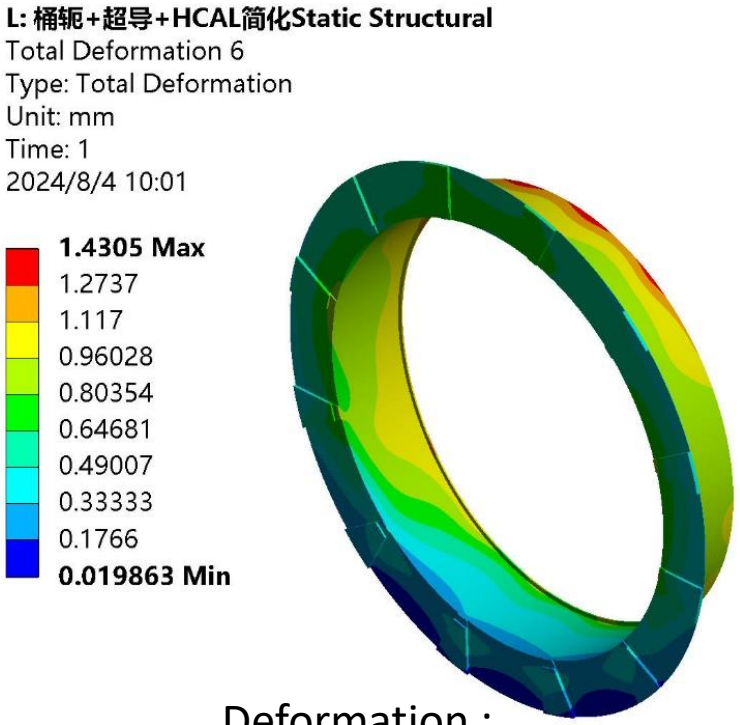
It's safety!

Deformation :
≈ 7.37 mm
Stress :
≈ 140.8 MPa

In the middle of the two connections



Conclusion :
Need improvement and optimization



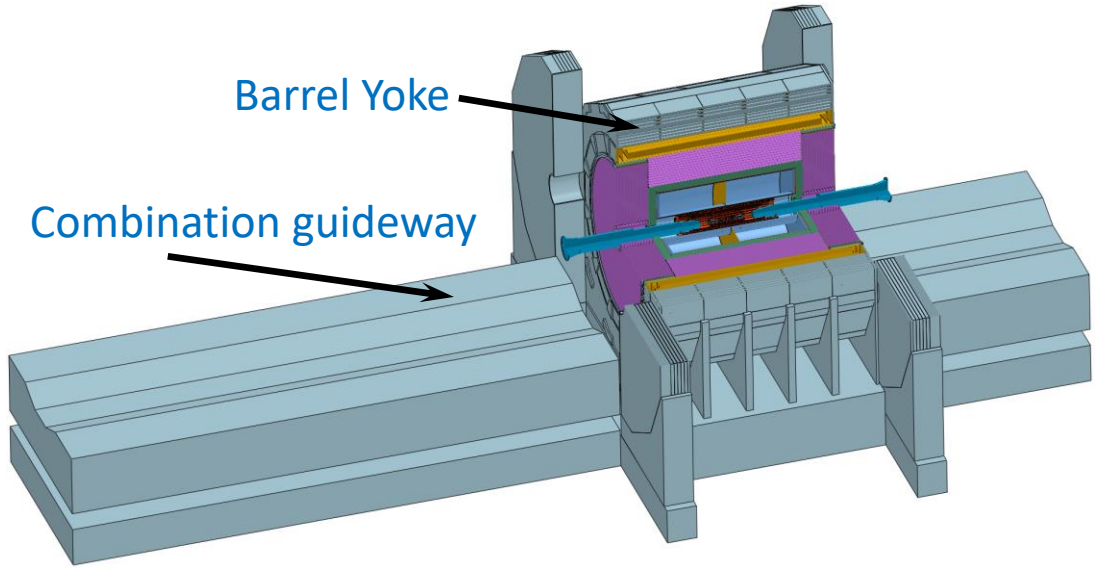
Deformation :
≈ 1.43 mm
Stress :
≈ 40.9 MPa

It's meet requirements

Overall installation concept design

Overall installation steps :

General installation drawing



> **Note:**
> Combination guideway is the installation reference, and is pre-aligned with the yoke

1. On the ground assembly room
   Complete the assembly work of each sub detector , including electronics, etc.

2. Each subdetector is lifted into the underground experimental room through vertical shafts in sequence

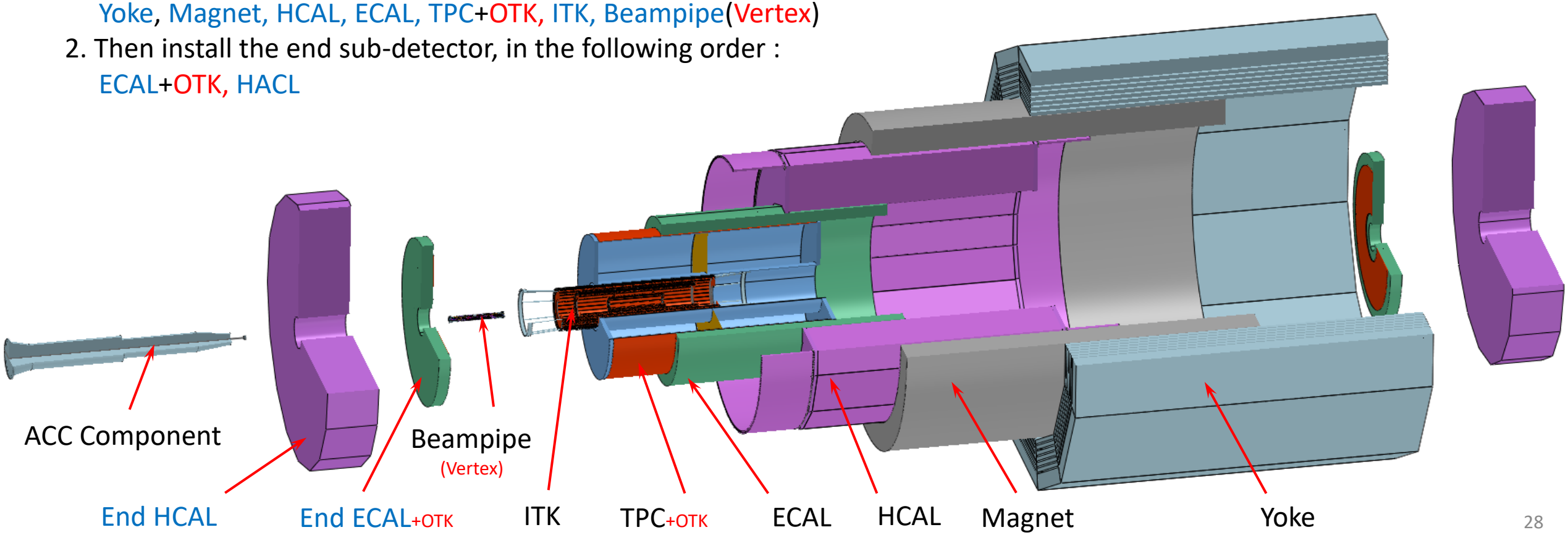
3. In the underground experimental room
   Assemble the sub-detectors on the combination guideway and push them into the yoke in sequence

Overall installation concept design

Detectors installation steps (As shown in the exploded view)

Installation sequence :

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-detector, in the following order :
   ECAL+OTK, HACL

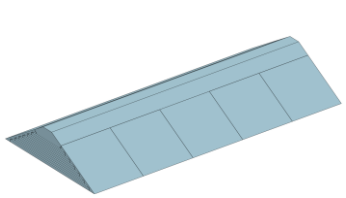


Overall installation concept design

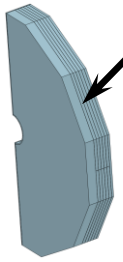
Considerations for integral and separate lifting of components

Lifted in Separate

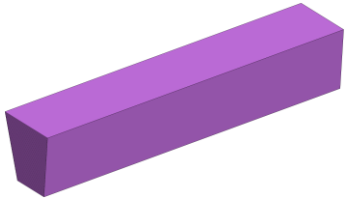
heaviest single module
≈ 400 t



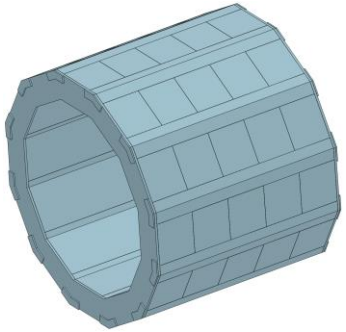
Yoke

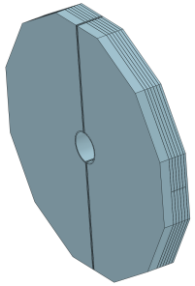


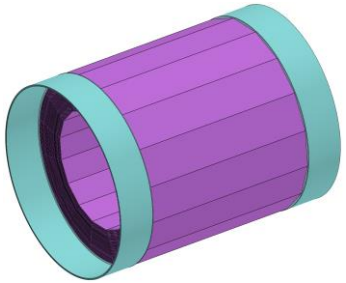
End Yoke



HCAL

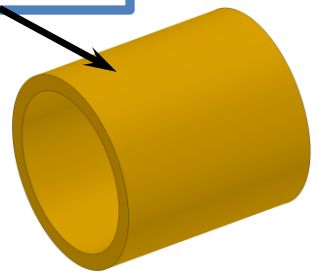




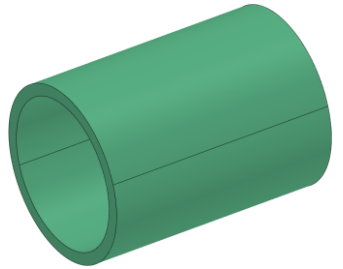


Lifted as a integral

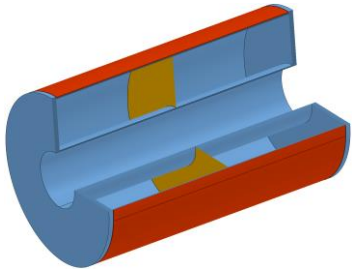
Largest single size
9050 L X Φ 8470



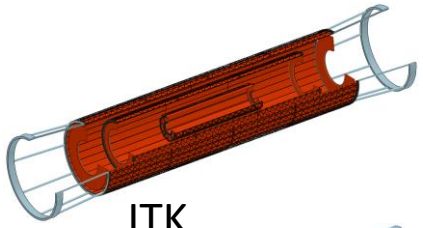
Magnet



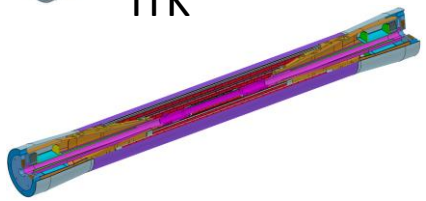
ECAL



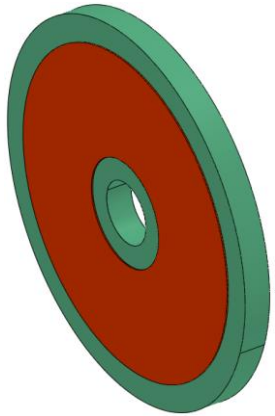
TPC+OTK



ITK



Beampipe

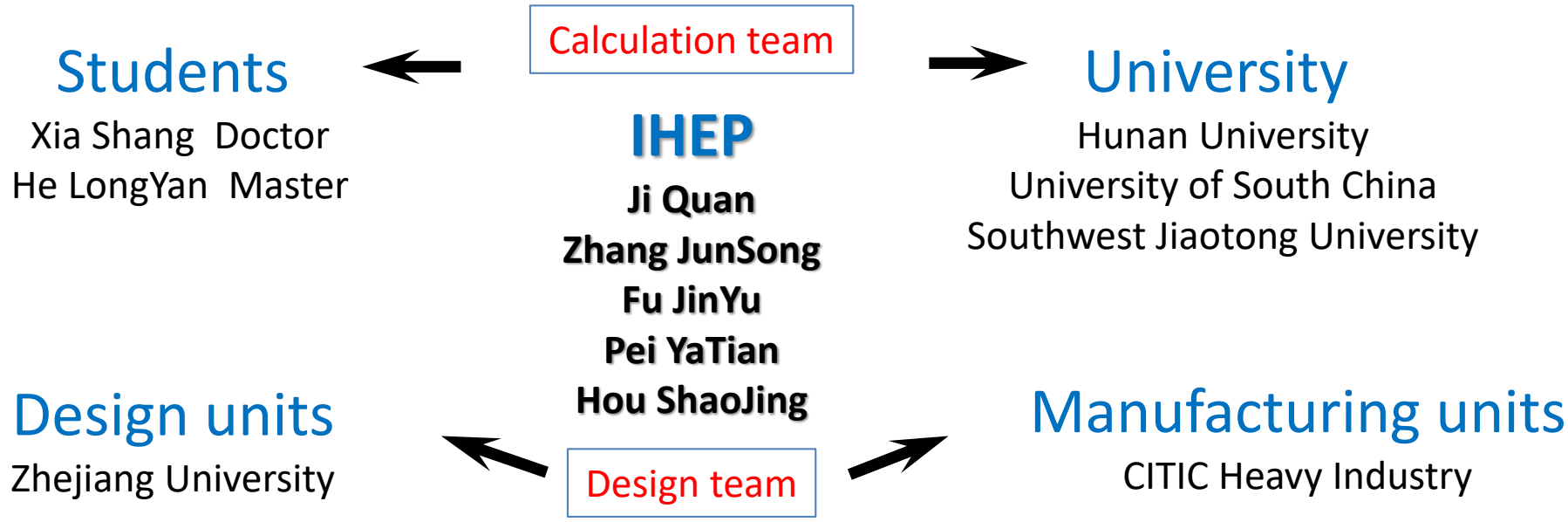


End - ECAL

End - HCAL

Research team

The mechanical team needs to be cultivated and diversified :



Enhance comprehensive abilities :

Global perspective, Comprehension ability, Communicate ability, Technological innovation capacity, etc.

Research team

Question and recommendation :

Question :

1. Most mechanical engineers are part-time workers
2. Serious shortage of human resources

Recommendation :

1. With the deepening and expansion of mechanical design,
   it is necessary to continuously increase the number of mechanical engineers

2. If human resources are sufficient, choose high-quality mechanical engineers as much as possible

Summary and working plan

Summary

1. The overall design requirements and the design requirements for each sub detector need to be further refined
2. The top-level installation design is basically clear, but further feasibility needs to be demonstrated

Summary and working plan

Working plan

1. Refine the installation plan and connection design of sub detectors
2. Complete the framework layout of the underground experimental room and its supporting room
3. Complete the layout of the ground room

Thank you for your attention!

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Institute of High Energy Physics
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