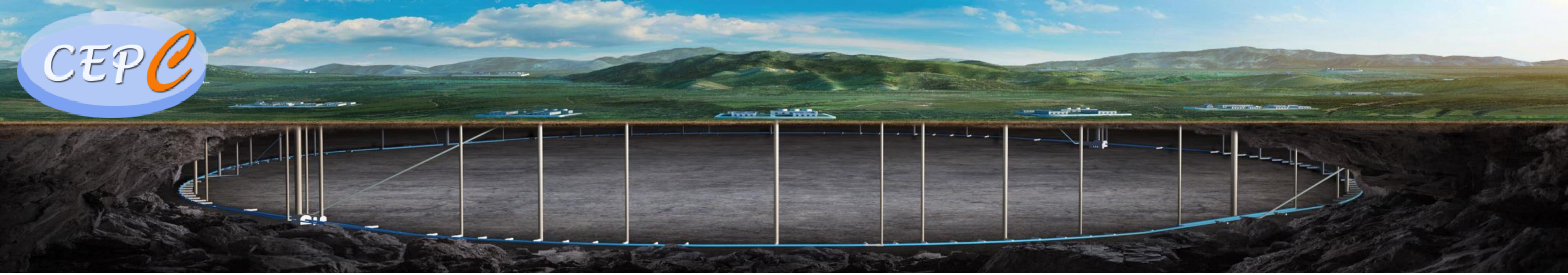

CEPC Detector Mechanical integration

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Chinese Academy of Sciences

Aug. 7th, 2024, CEPC Detector Ref-TDR Review

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 the 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 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)

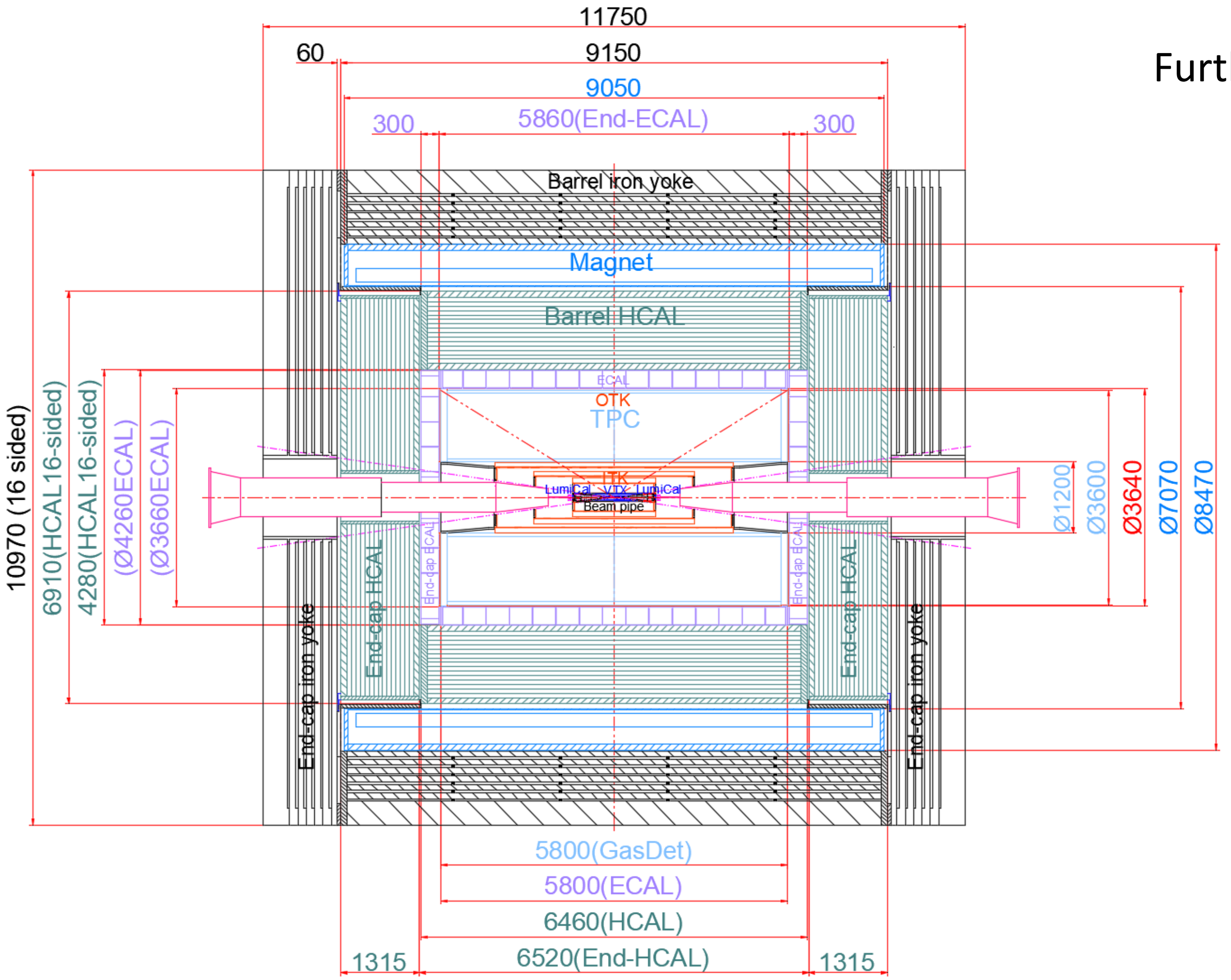
Overall Design Progress :

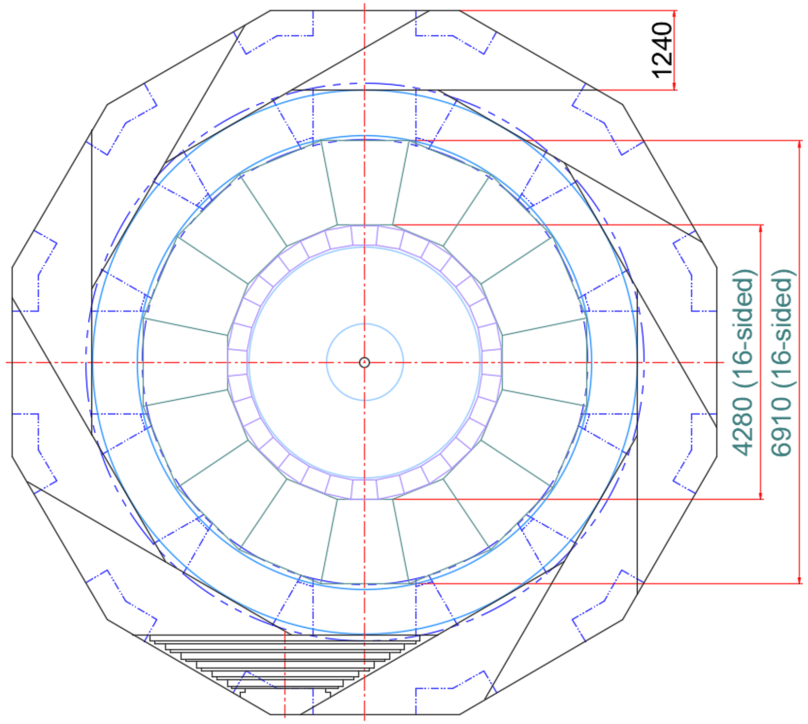
1. Initial mechanical overall layout drawing
2. Initial configuration drawing between the detectors and the underground experiment room
3. Basic frame structure design of the sub-detectors

Introduction

Mechanical integration progress : Initial Size distribution

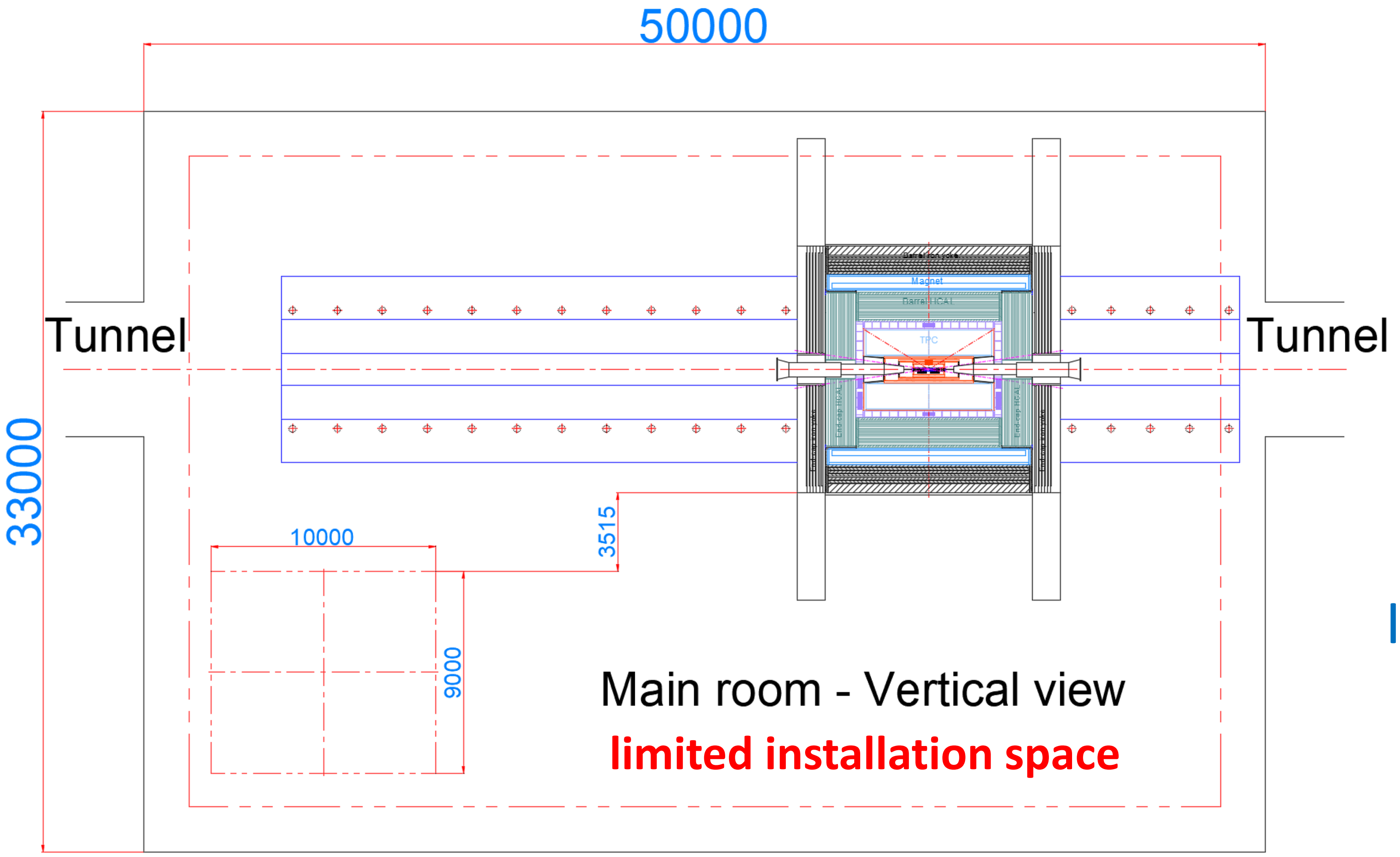
Further optimization and improvement are needed





Introduction

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



Installation location :

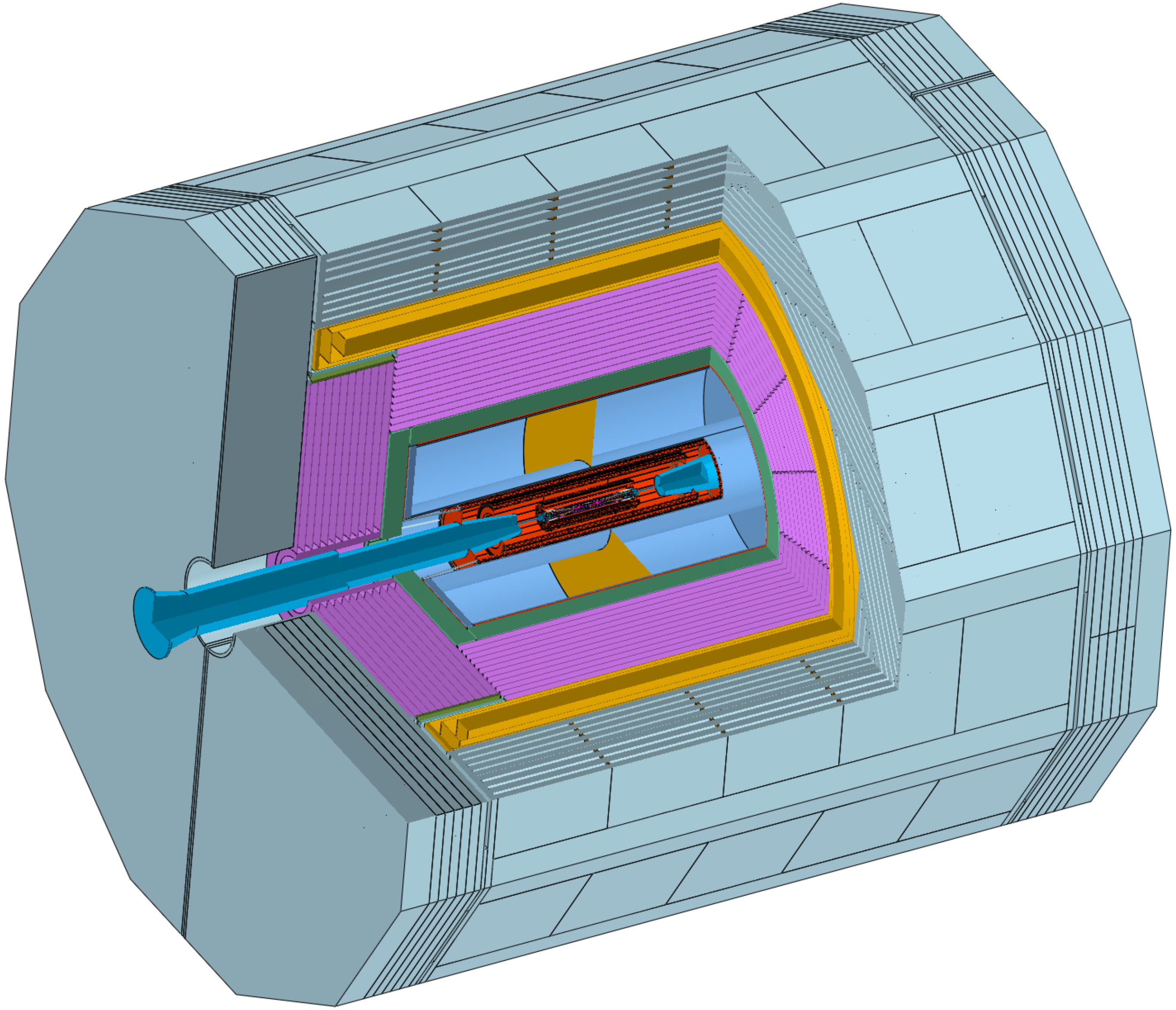
Collision point

Introduction

Total weight :

≈ 6000 t

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



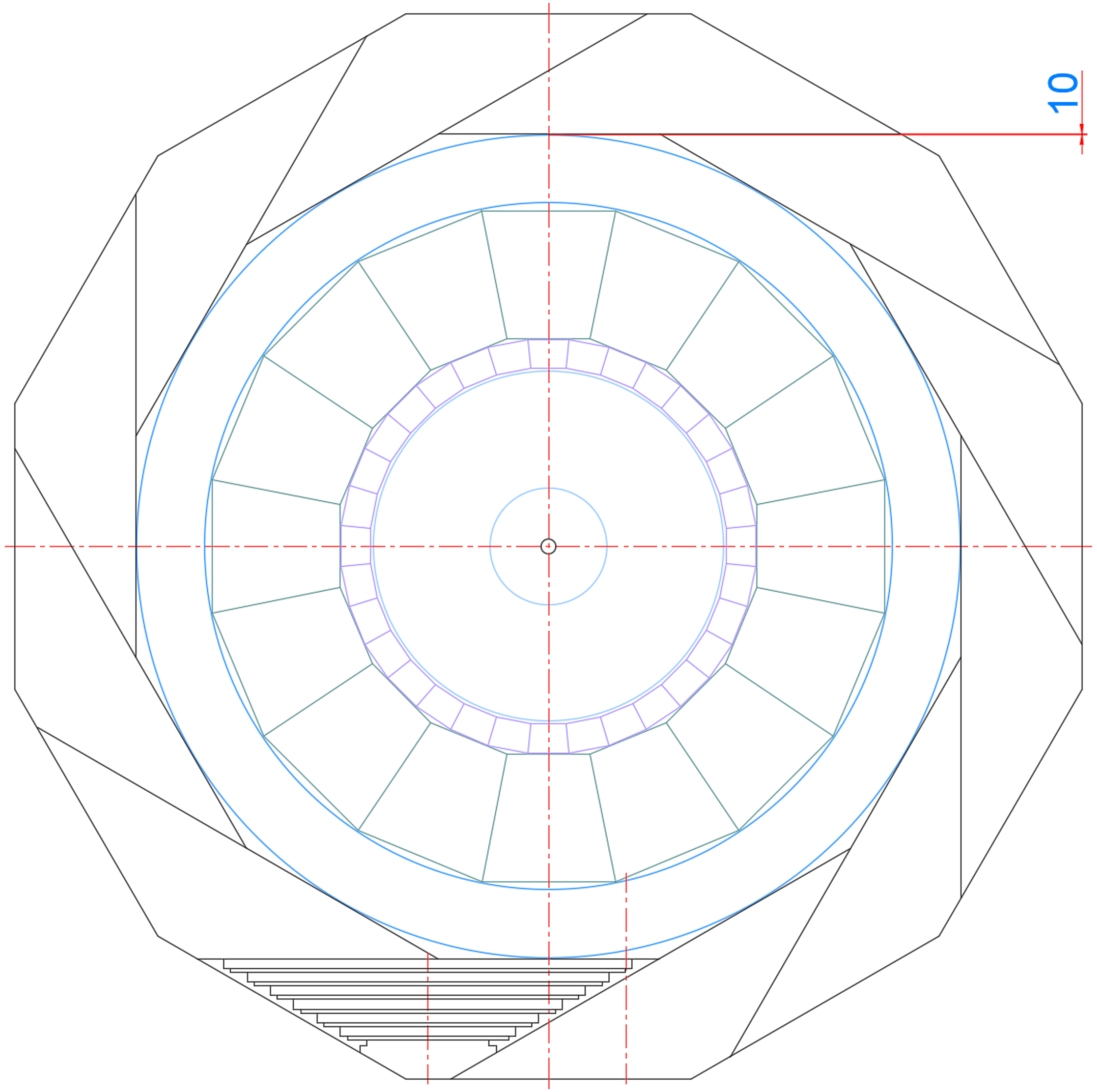
Requirements

Minimum gap principle :

As small as possible

Gap between sub detectors :

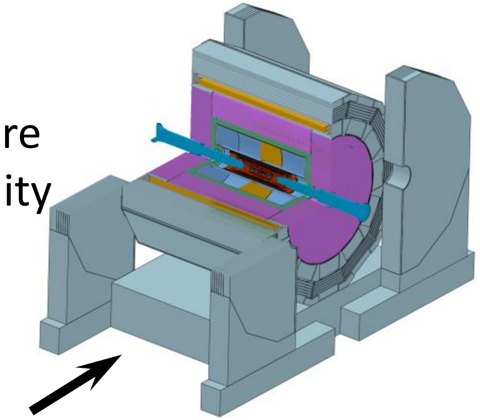
Installation gap : ≤ 10mm



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

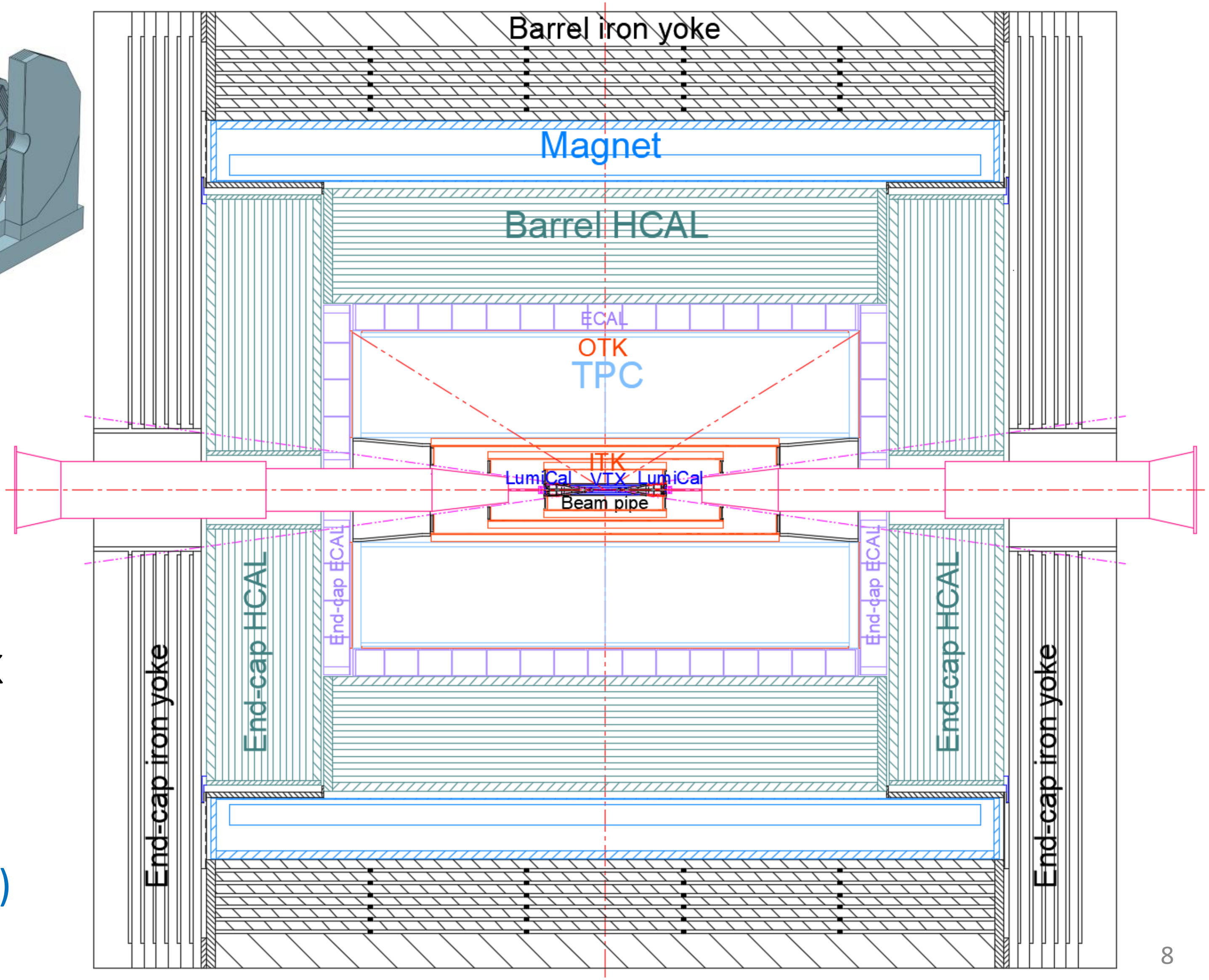
ITK : Fixed on the TPC

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)

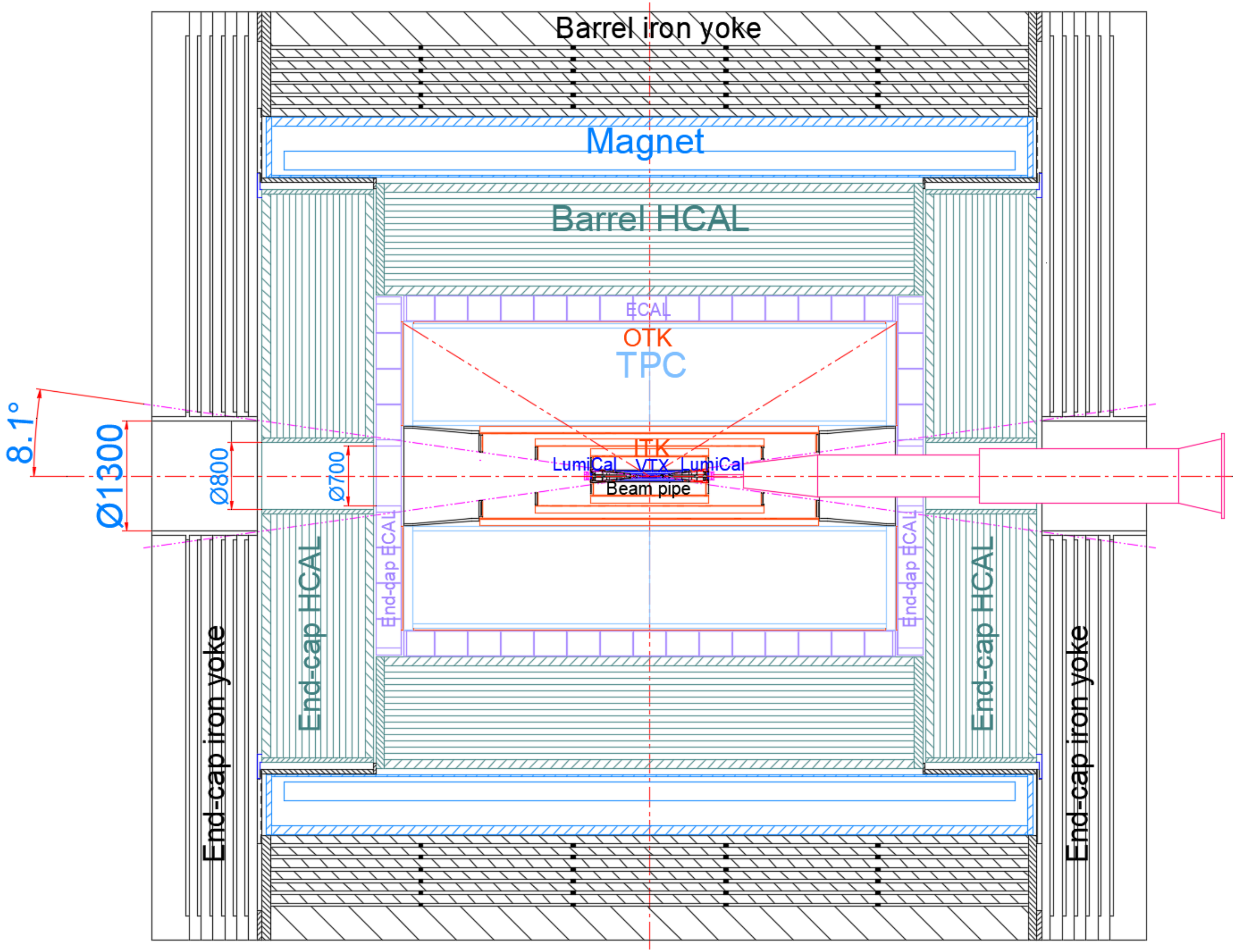
(After ECAL)

ECAL : Ø700 mm

HCAL : Ø800 mm

Yoke : Ø1300 mm

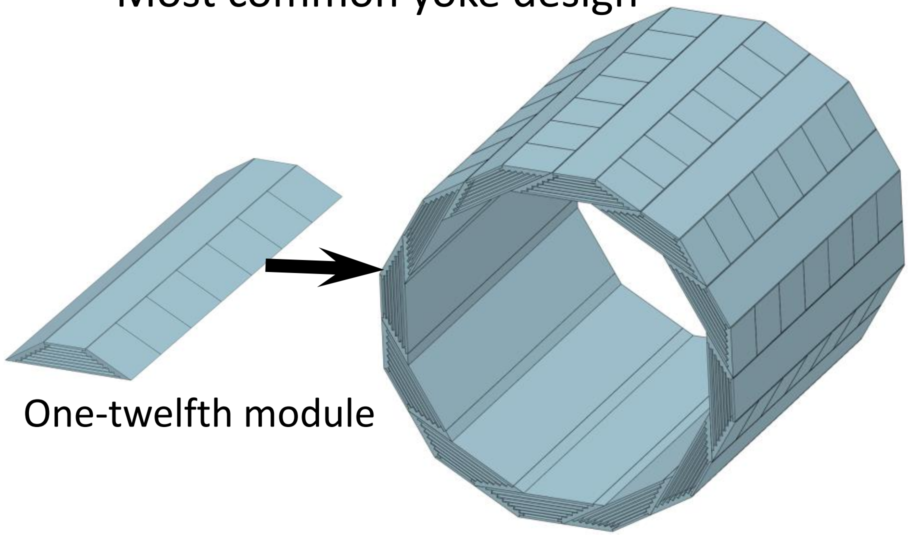
Conical hole and stepped holes are reserved spaces for accelerators

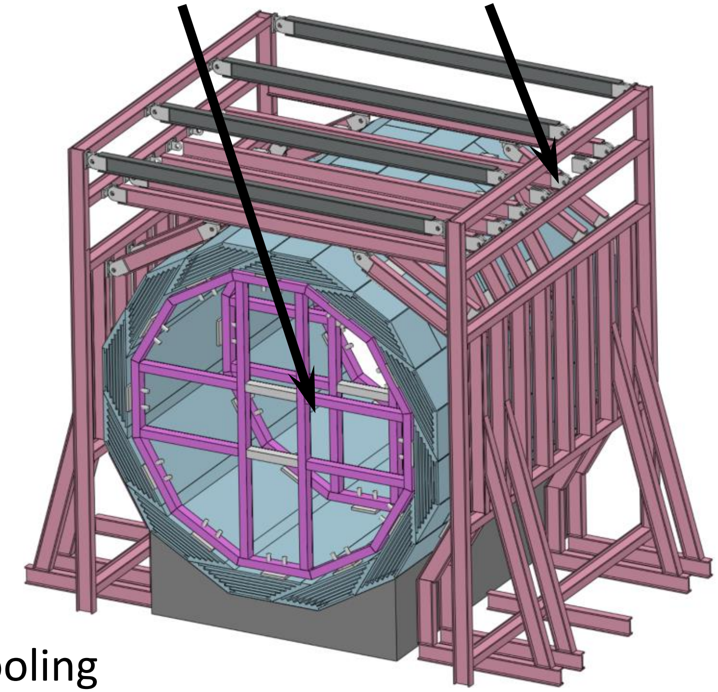


Technical challenges

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

1. The installation design of zero-assist Tools for Barrel Yoke





Typical installation design :

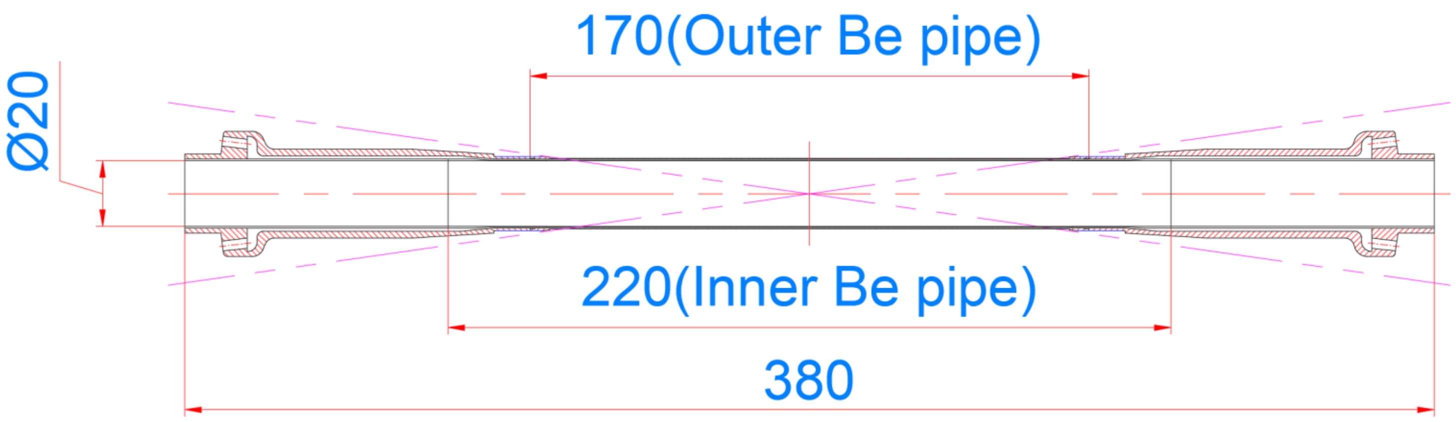
Assembly must be possible with the help of the auxiliary tooling

If there are no auxiliary fixtures, how can the 12 modules be assembled together?
And its assembly accuracy is very high

Technical challenges

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

2. Processing of thin-walled beryllium pipe



Size of outer Be pipe: 0.15 X 170 mm
Size of inner Be pipe: **0.20 X 220mm**

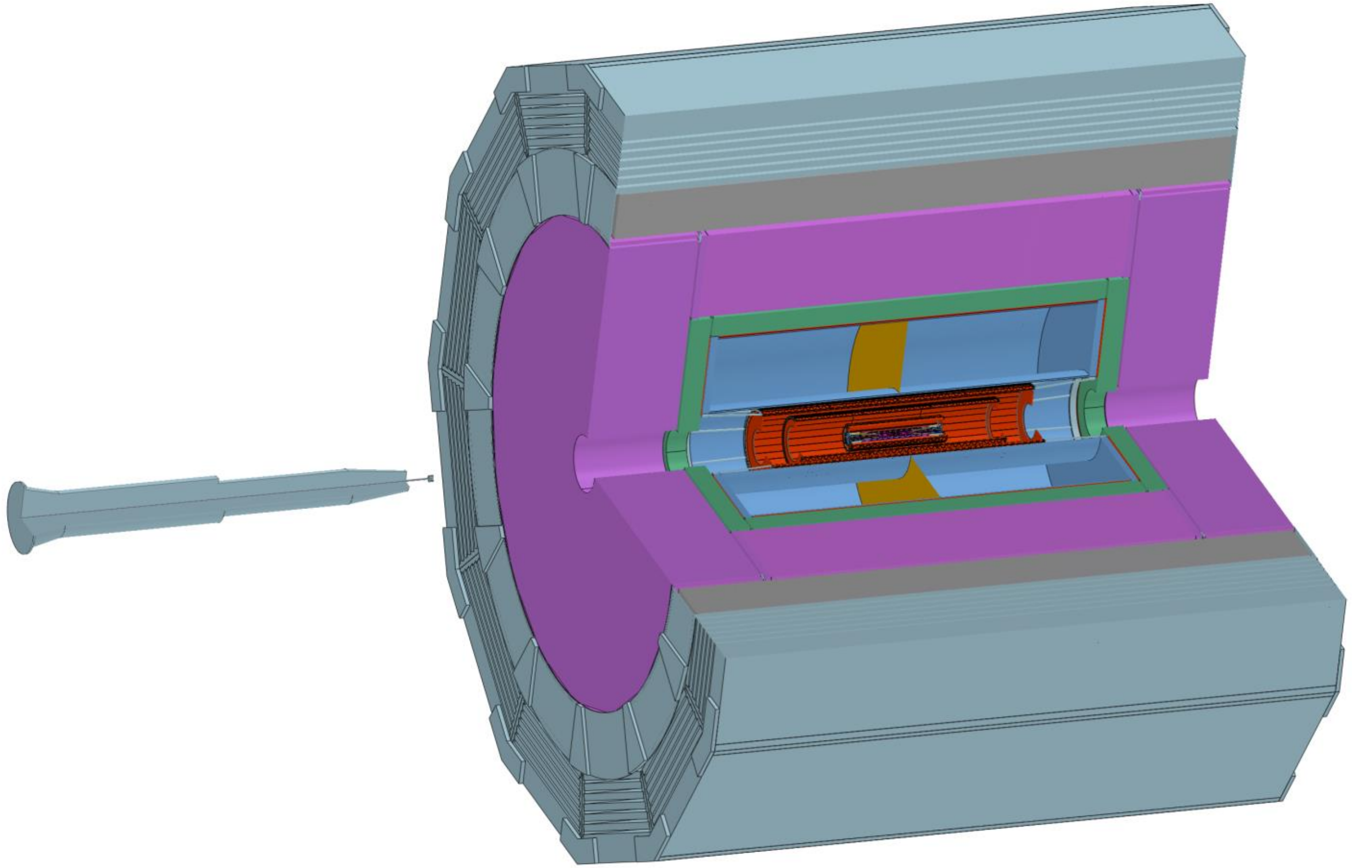
Processing capability : **0.2 X 100 mm**

Development of longer beryllium pipe technology is required

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

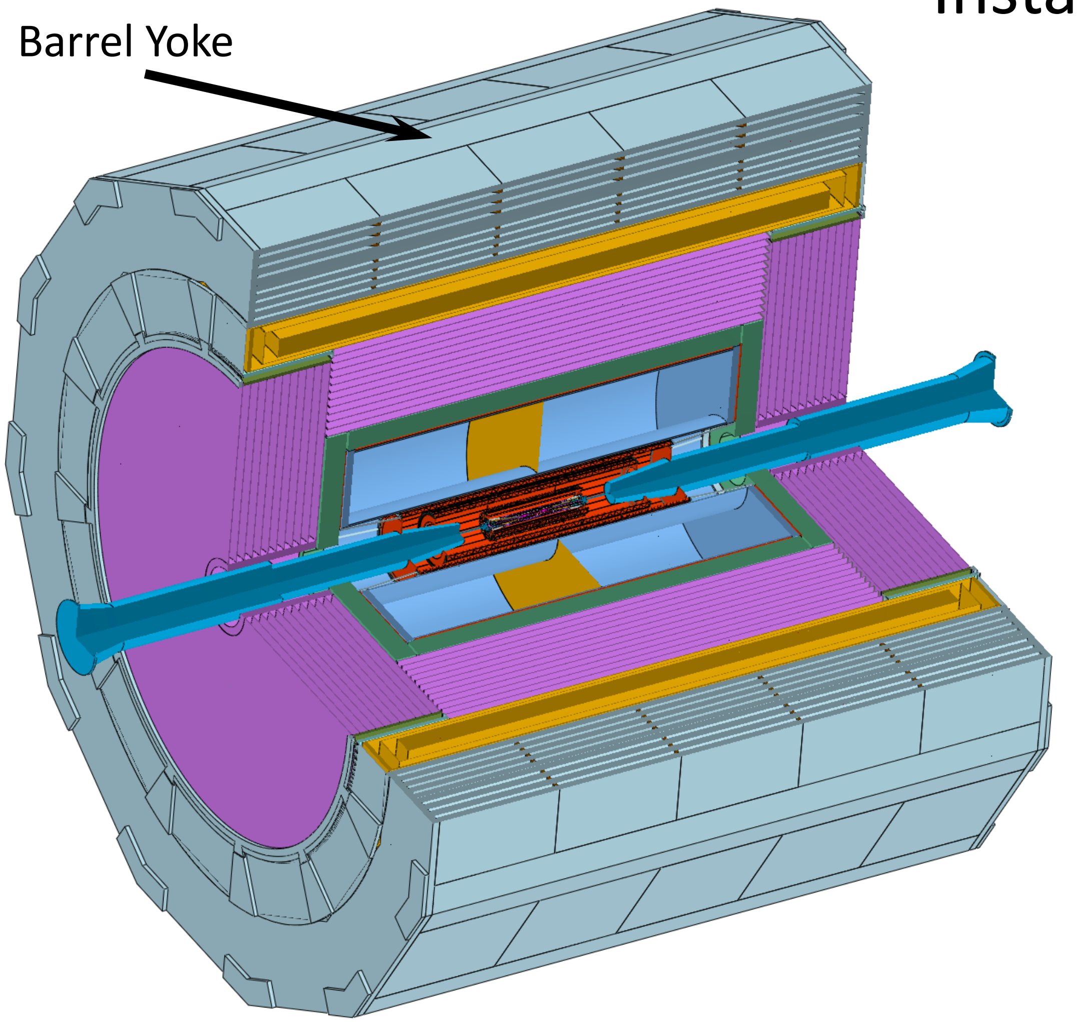
Technical difficulties :

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

Need to improve and develop current technology

Pillow seal can be used for remote vacuum automatic connection

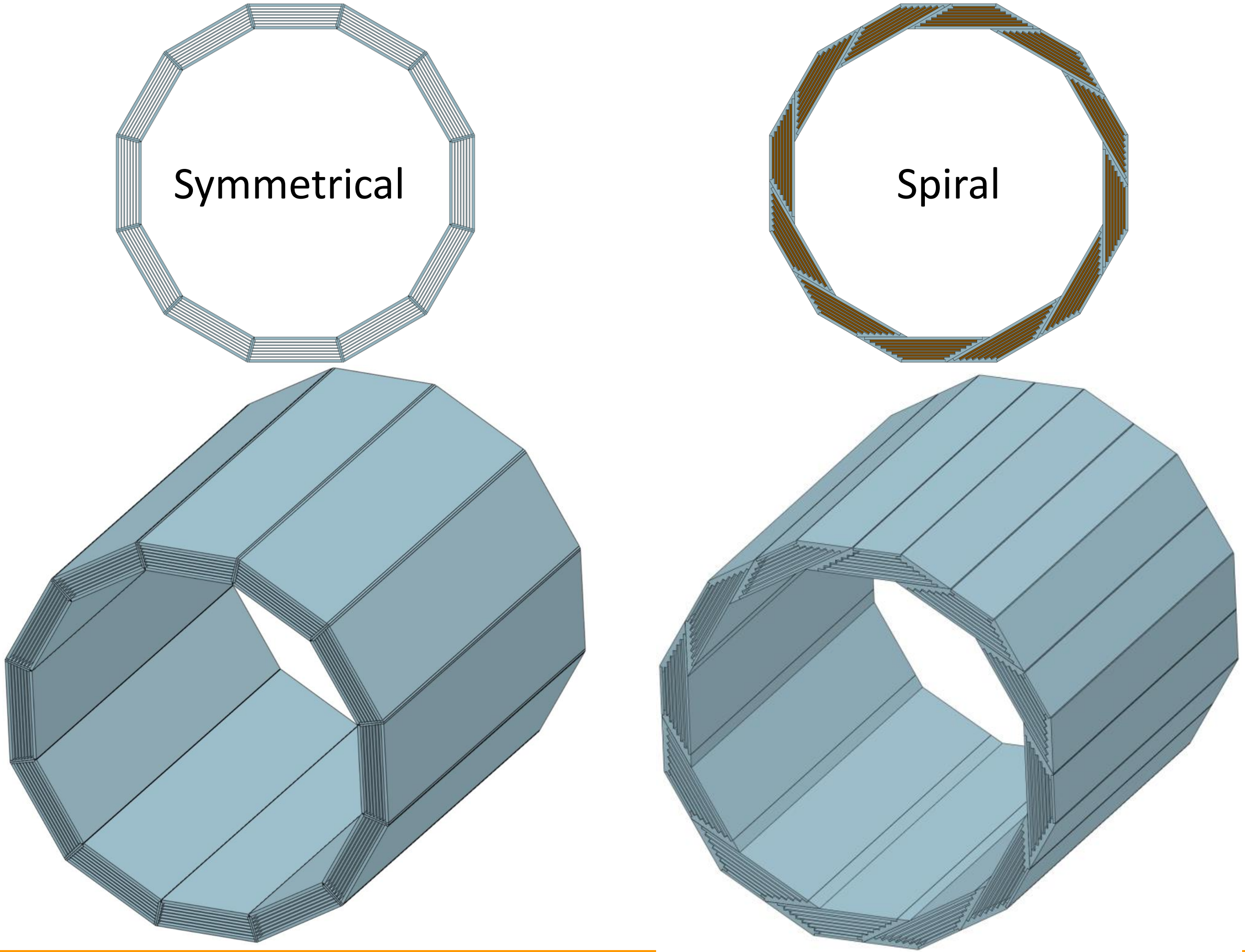
Comparison and selection of different schemes



Start with optimizing the structural design of the yoke

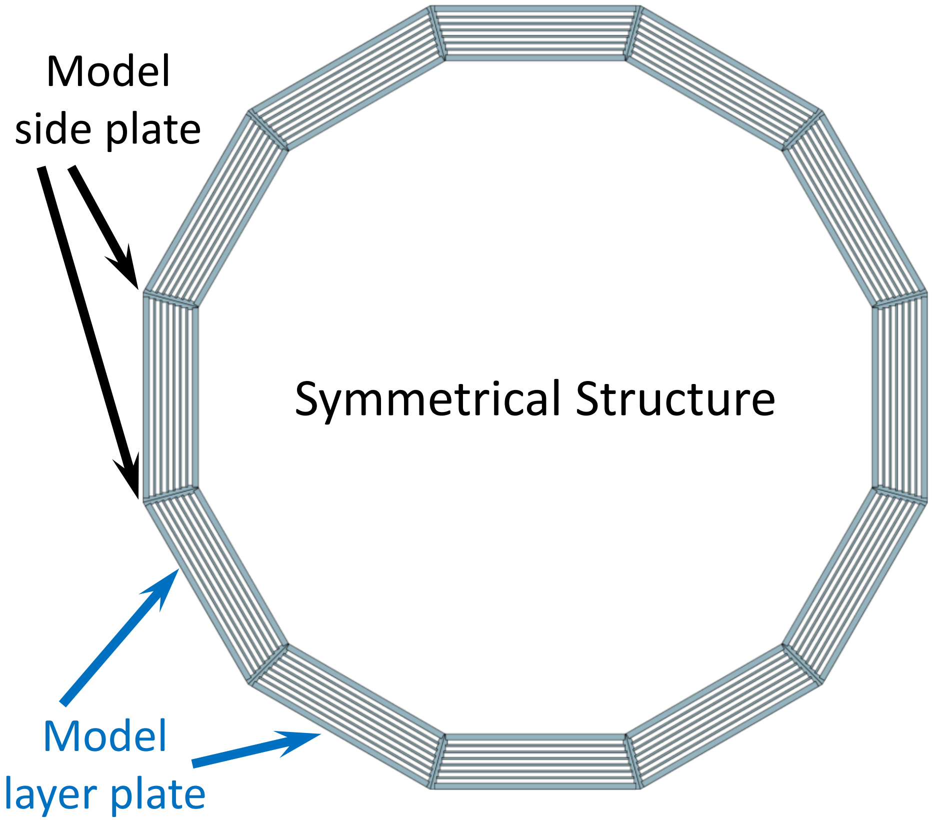
Installation scheme design starts from the yoke

Comparison and Selection :

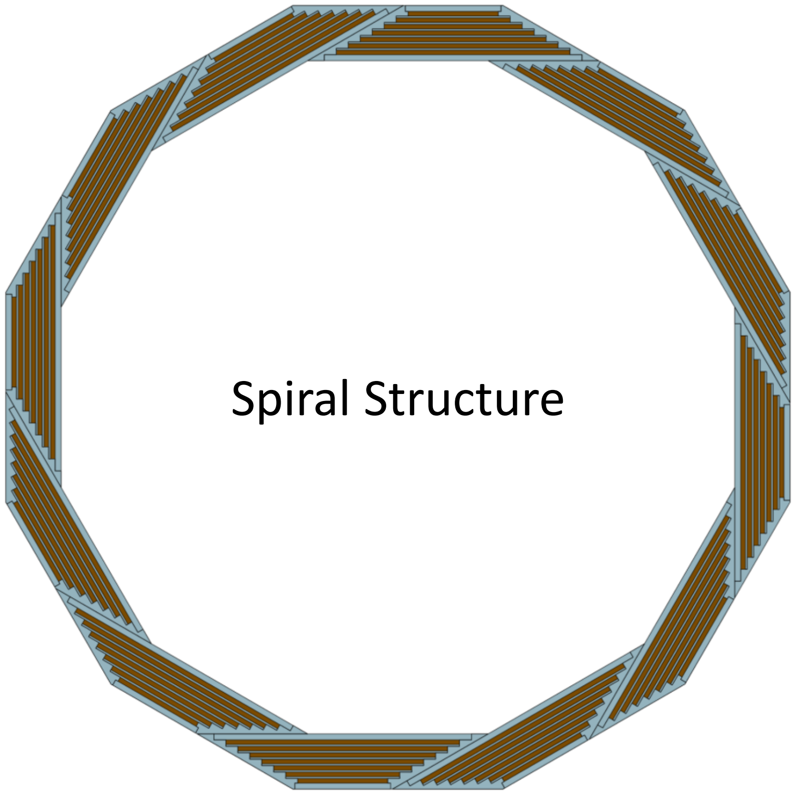


Comparison and selection of different schemes

From the perspective of Muon detector design :



Drawing 1



Drawing 2

Drawing 1 :

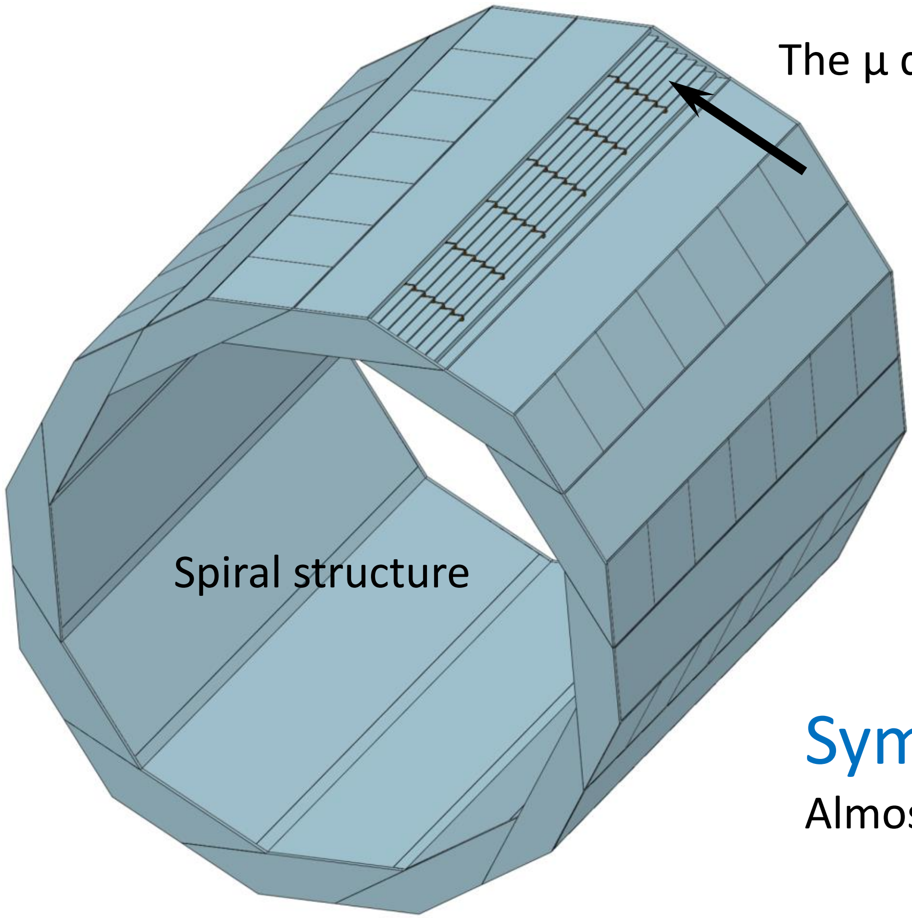
Undetectable blind zones

Drawing 2 :

No detect blind zones

Comparison and selection of different schemes

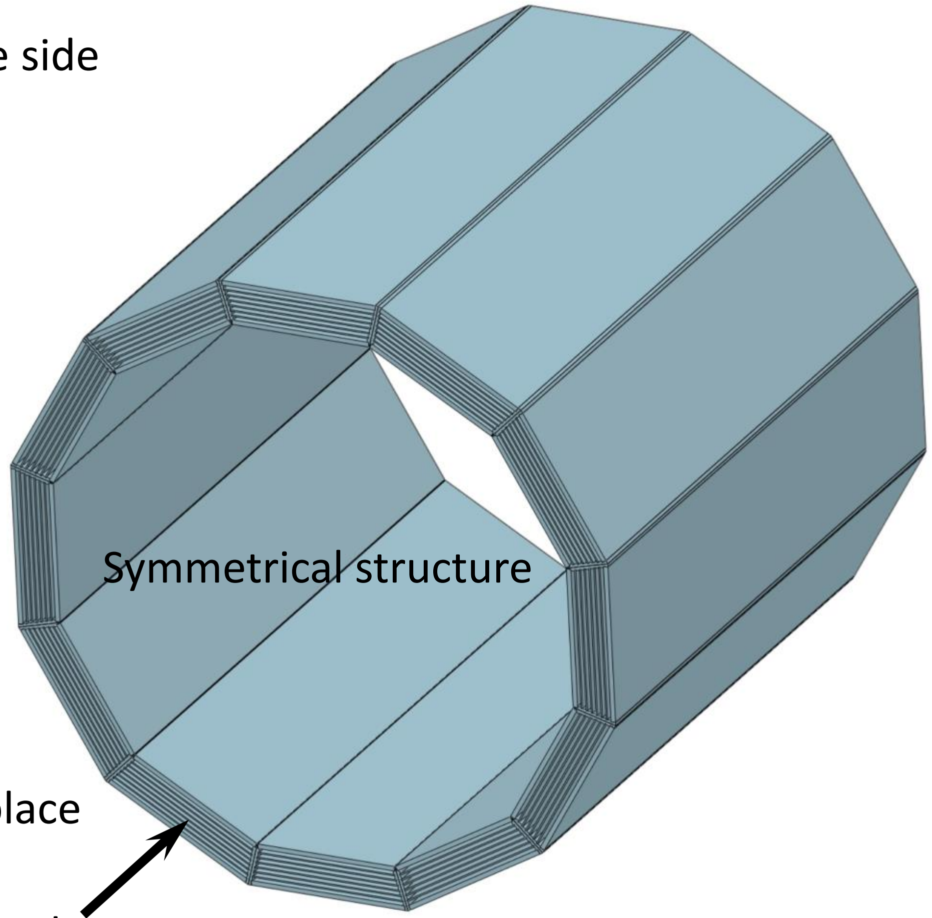
From the perspective of maintenance design :



The μ detector can be installed from the side

Spiral structure :

Easy to maintain and replace



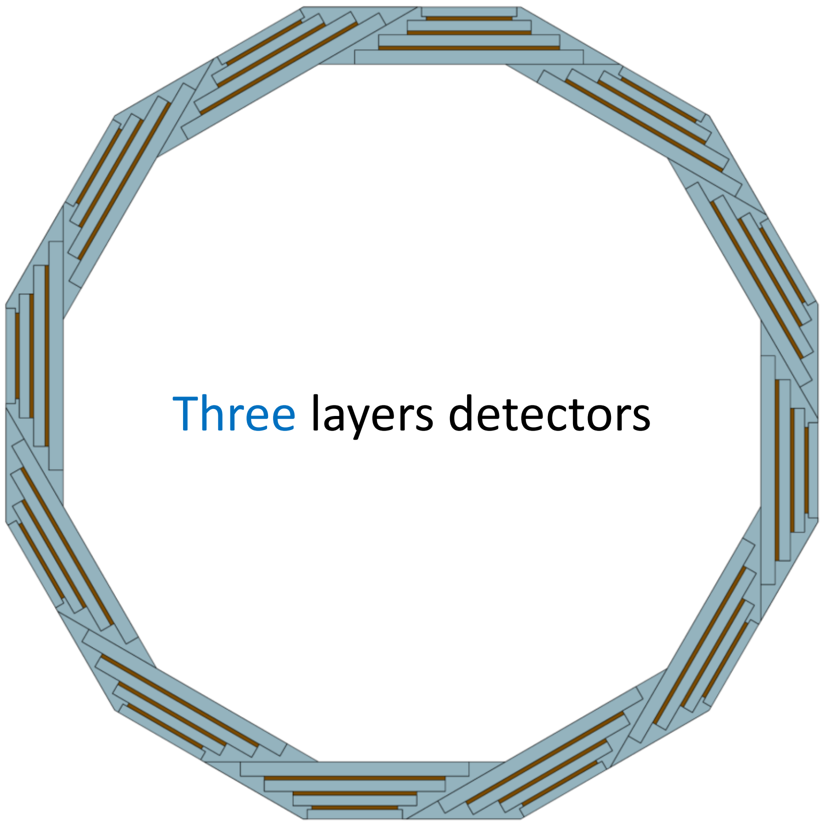
Symmetrical structure :

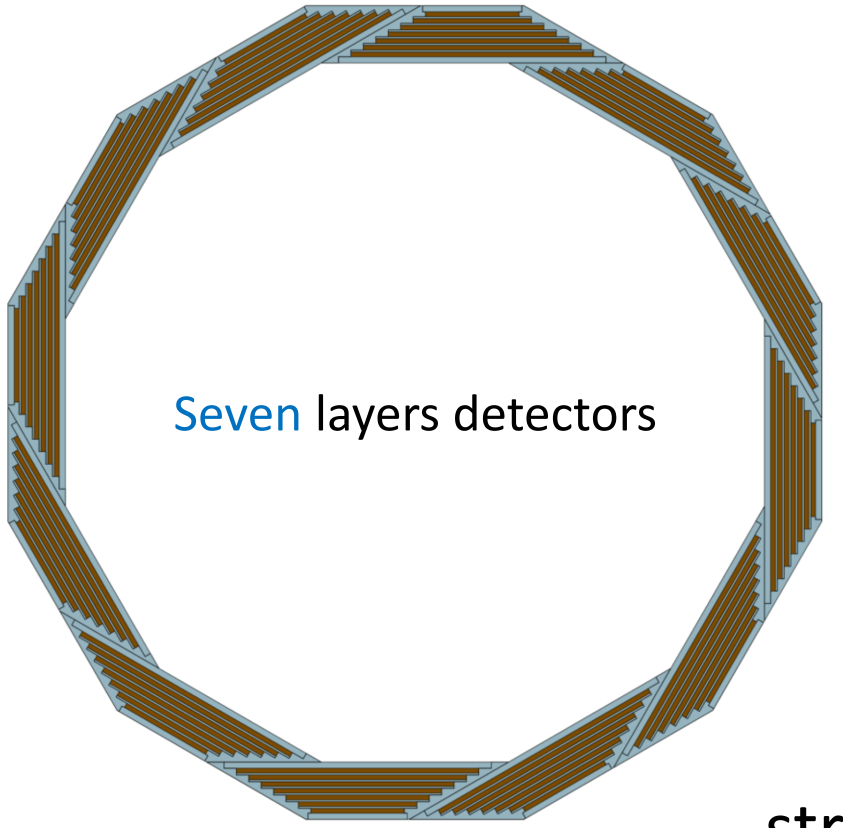
Almost impossible to maintain and replace

The μ detector can be installed from the both end

Comparison and selection of different schemes

From the perspective of muon detector and mechanical strength :





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

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

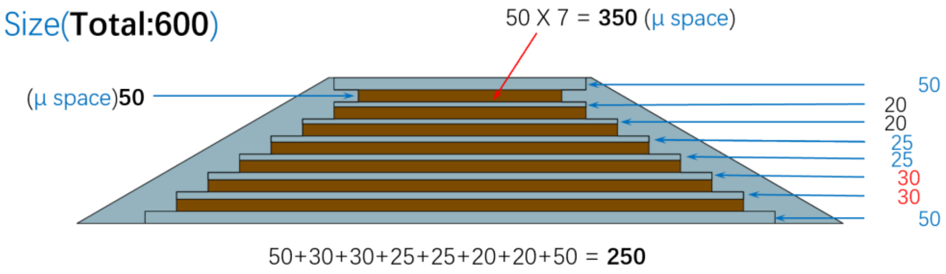
Seeking the optimal structure and parameters

Comparison and selection of different schemes

From the perspective of
deformation control :

Baseline Parameters

(Comparison and selection)



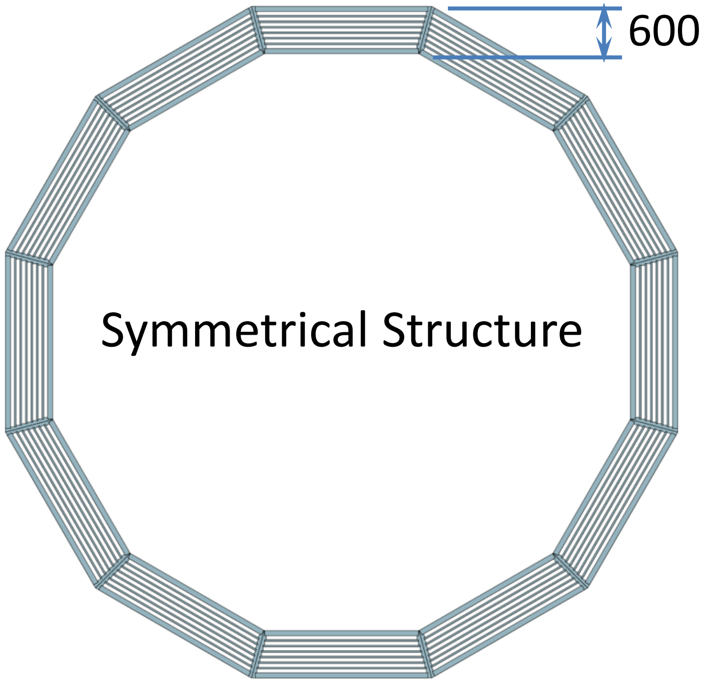
Requirements :

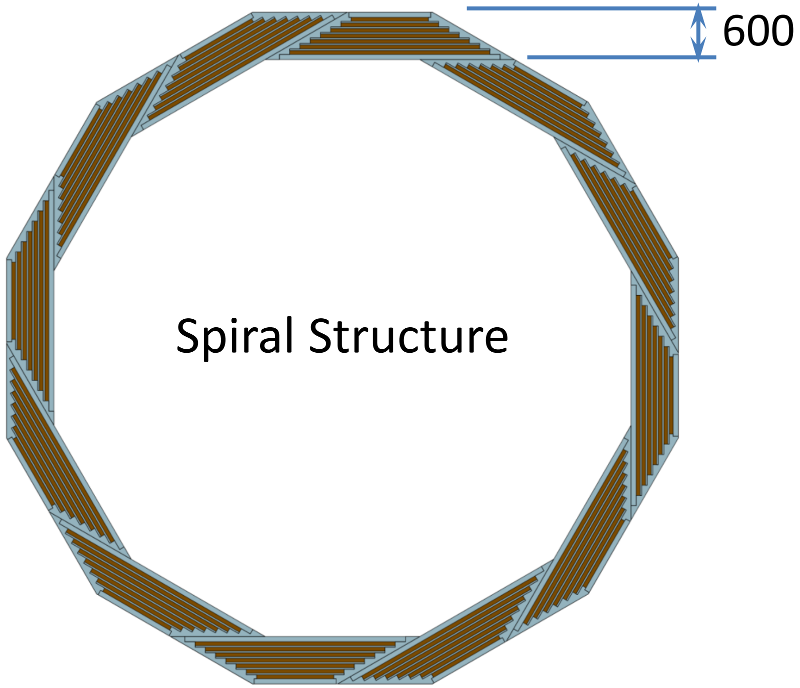
Tolerance :

10970±1

↓

Meet : < 1 mm

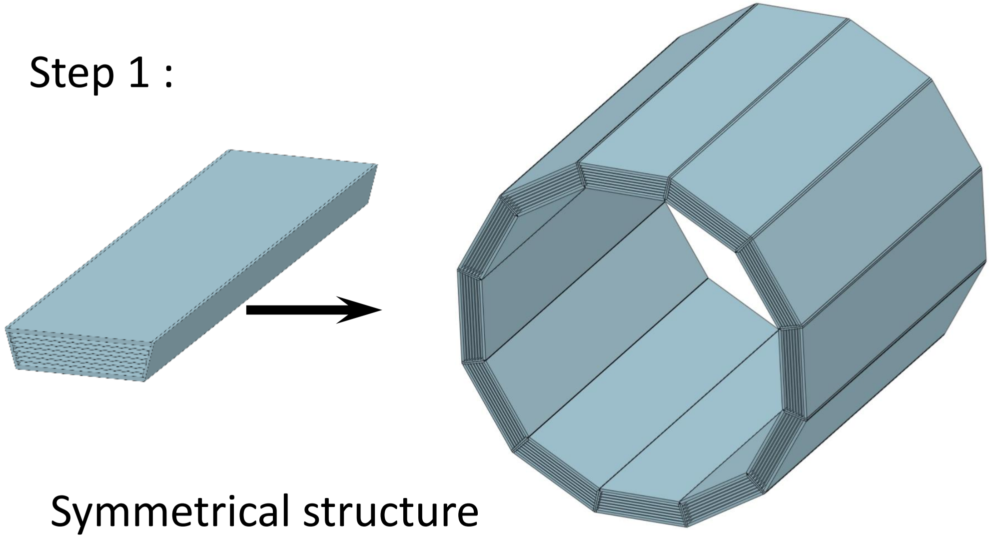




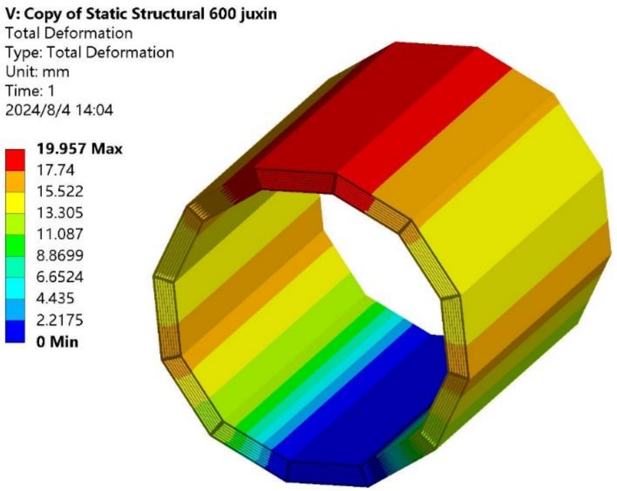
Comparison and selection of different schemes

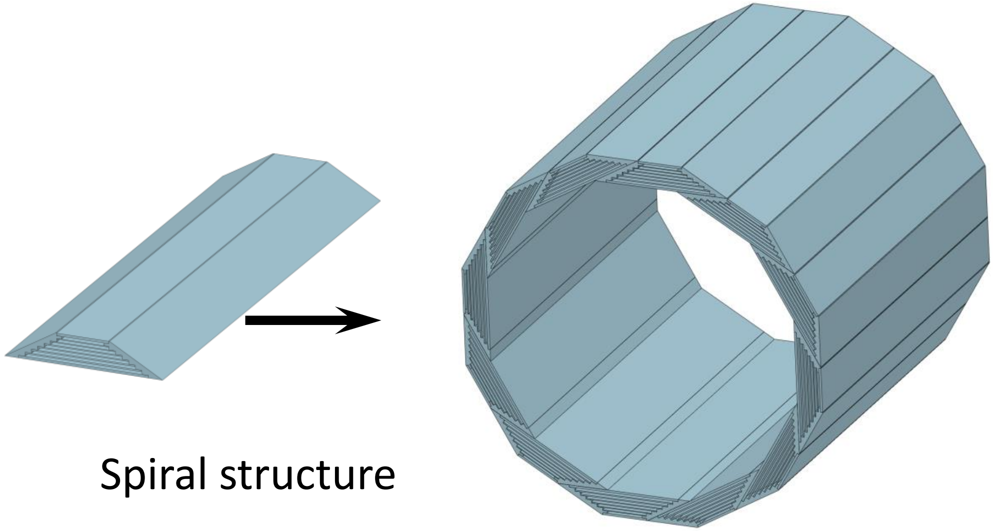
From the perspective of deformation control :

Step 1 :

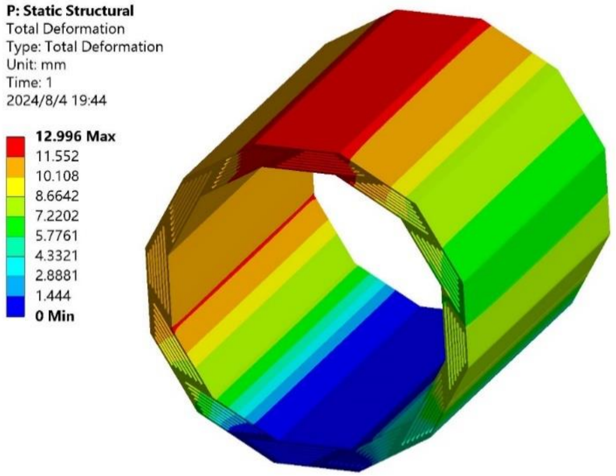


Symmetrical structure





Spiral structure



The spiral structure is more resistant to self-weight deformation

Self-weight deformation :

≈ 20.00 mm

Comparison :

Symmetrical

Spiral

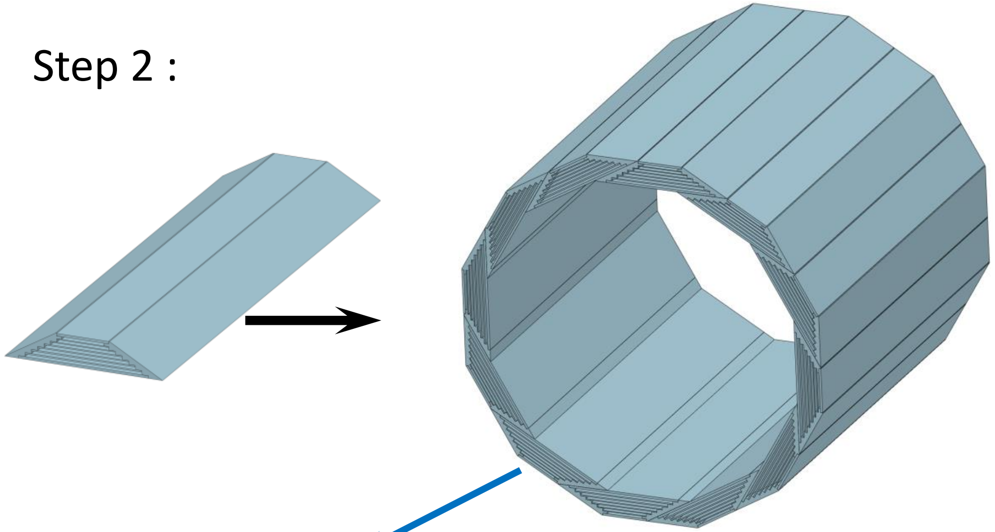
Self-weight deformation :

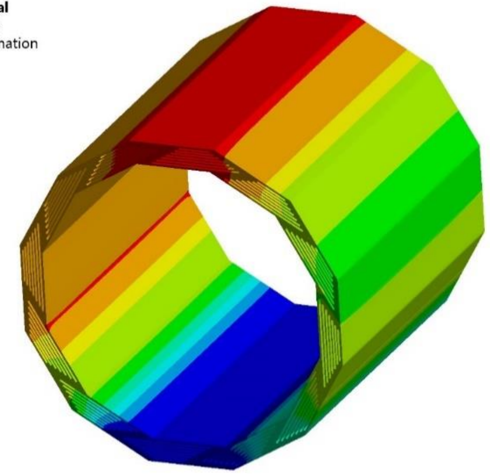
≈ 13.00 mm

Comparison and selection of different schemes

From the perspective of deformation control :

Step 2 :

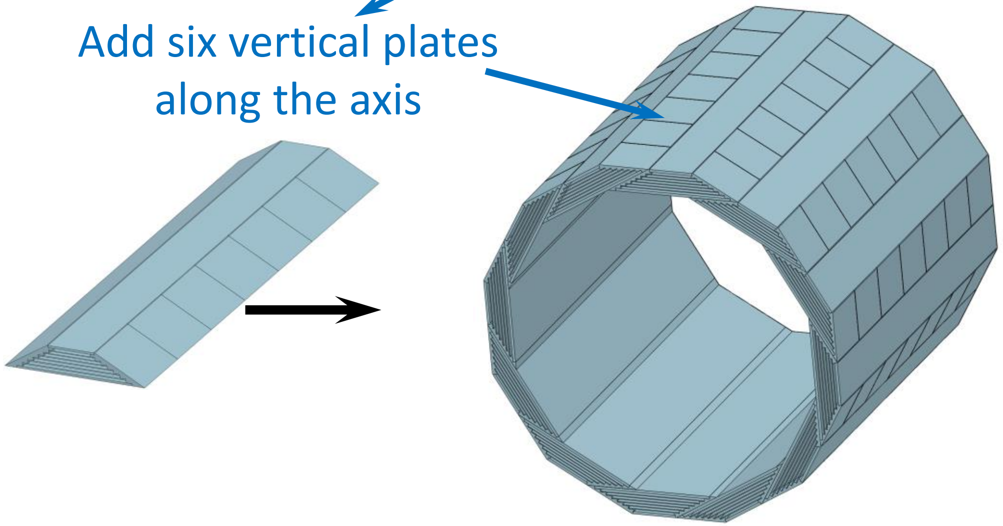


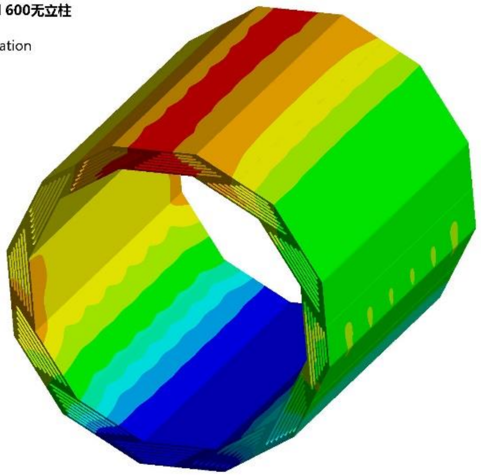


Self-weight deformation :

≈ 13.00 mm

Add six vertical plates along the axis





Self-weight deformation :

≈ 1.76 mm

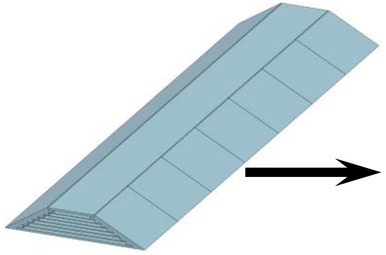
Comparison :

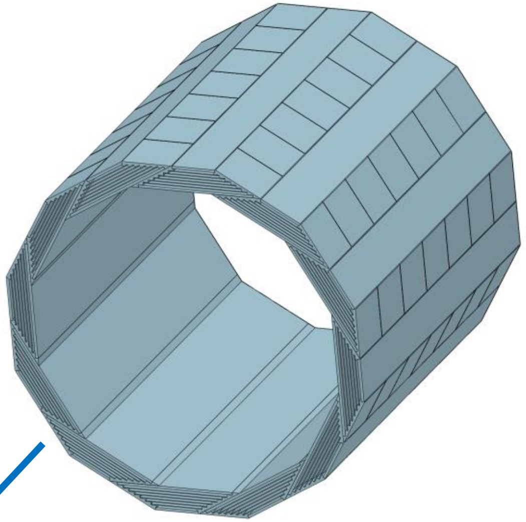
Parameters

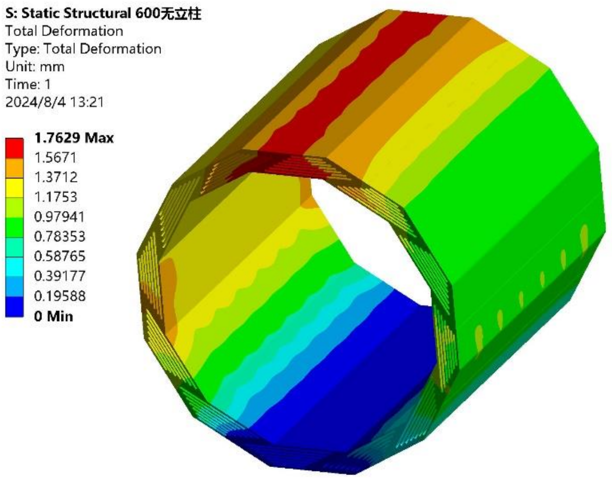
Comparison and selection of different schemes

From the perspective of deformation control :

Step 3 :

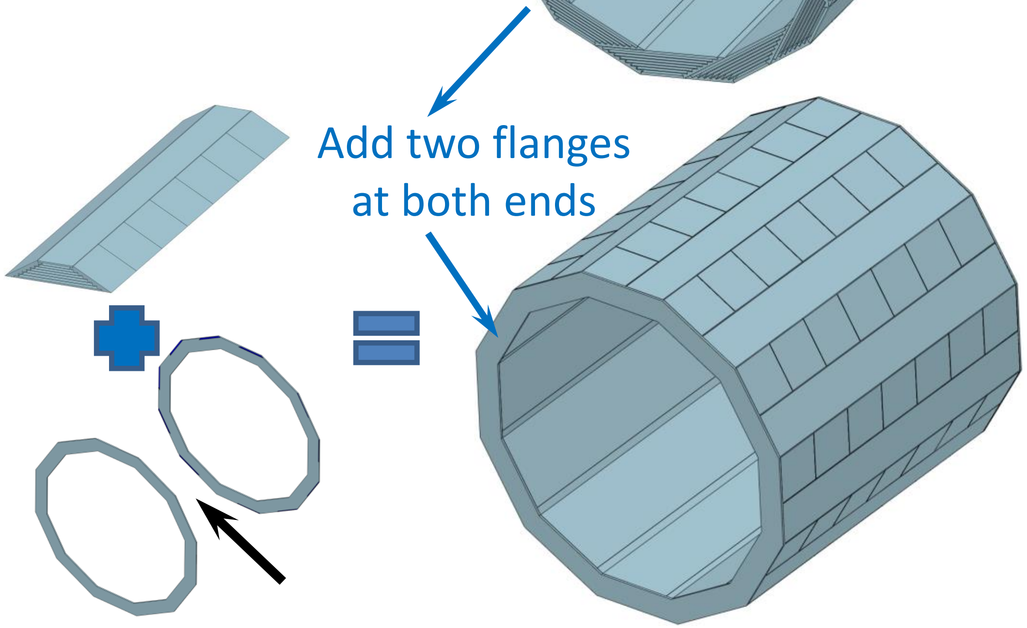


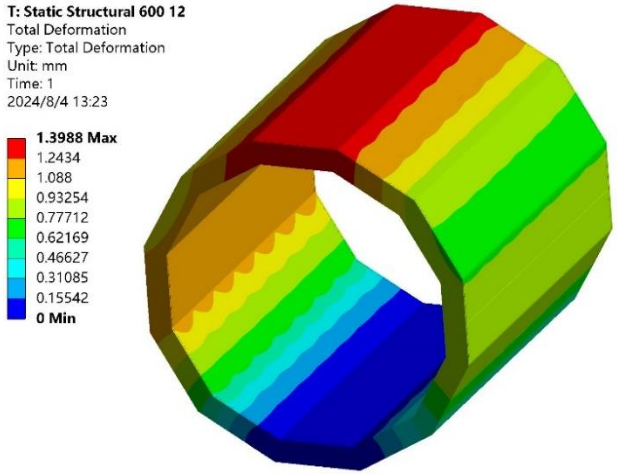




Self-weight deformation :

≈ 1.76 mm





Self-weight deformation :

≈ 1.40 mm

Comparison :

With flanges

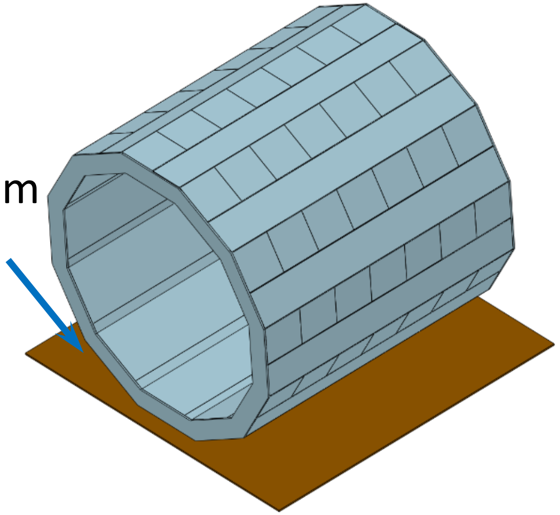
Without flanges

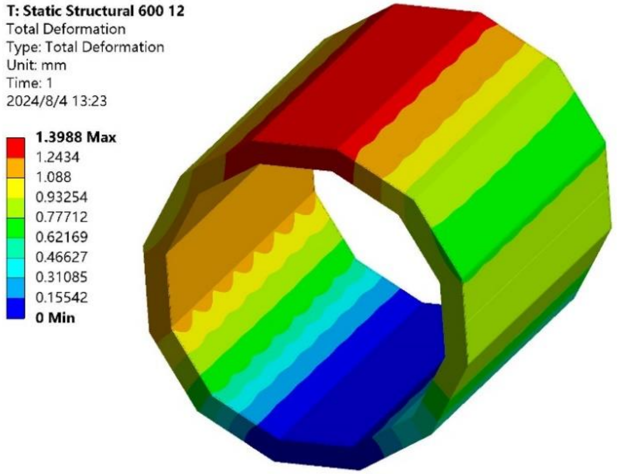
Comparison and selection of different schemes

From the perspective of deformation control :

Step 4 :

The flange bottom is suspended





Self-weight deformation :

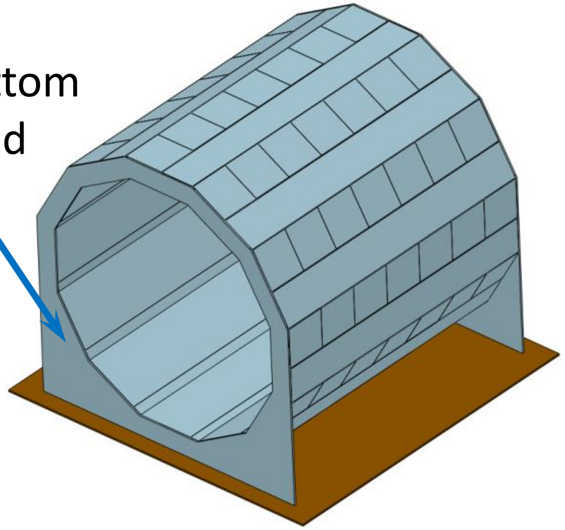
≈ 1.40 mm

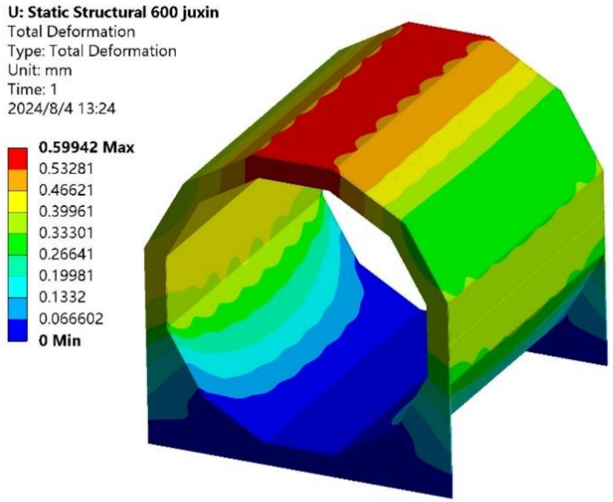
Comparison :

Suspended

Supported

The flange bottom is supported





Self-weight deformation :

≈ 0.6 mm

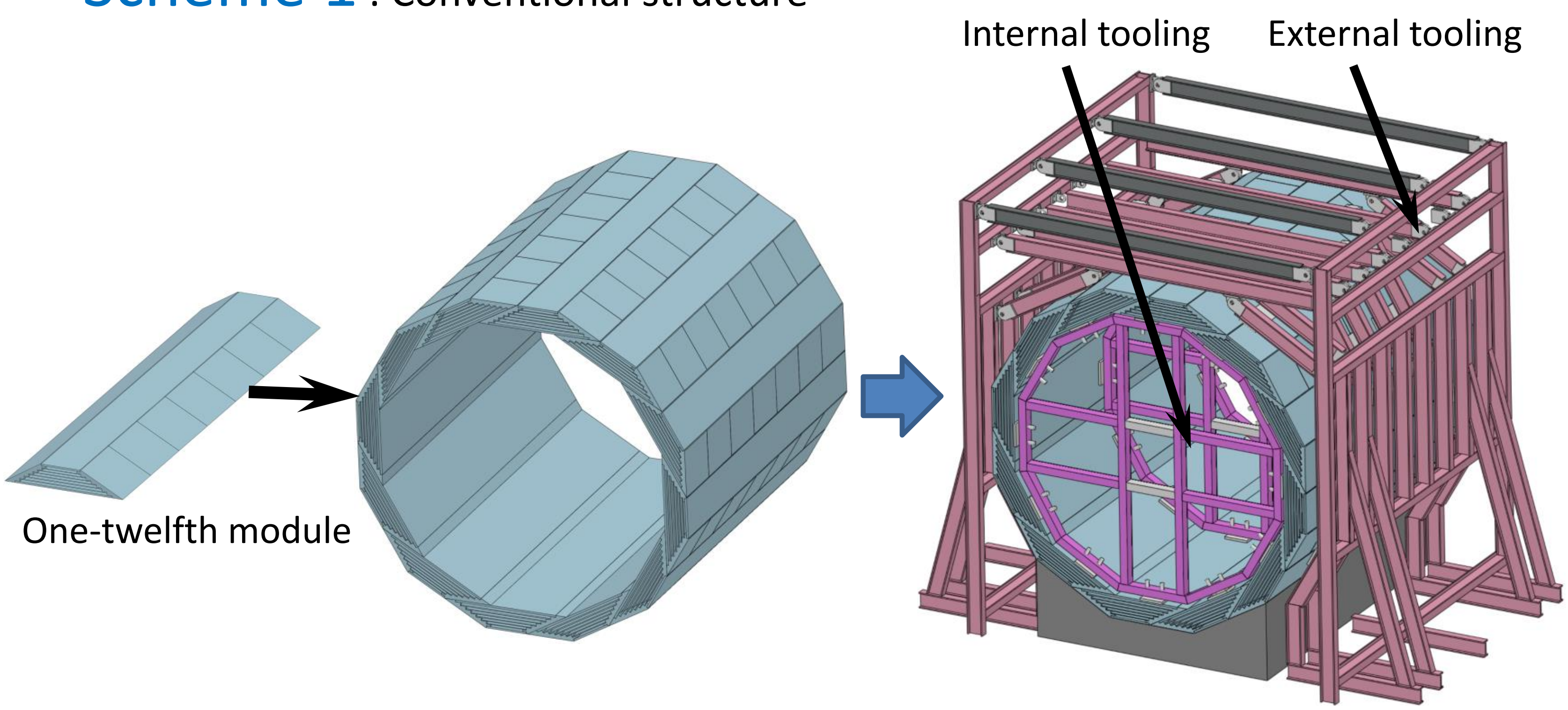
Meet : < 1 mm

Comparison and selection of different schemes

From the perspective of installation design :

Key : Different structural designs result in different installation designs

Scheme 1 : Conventional structure



Shortcomings :

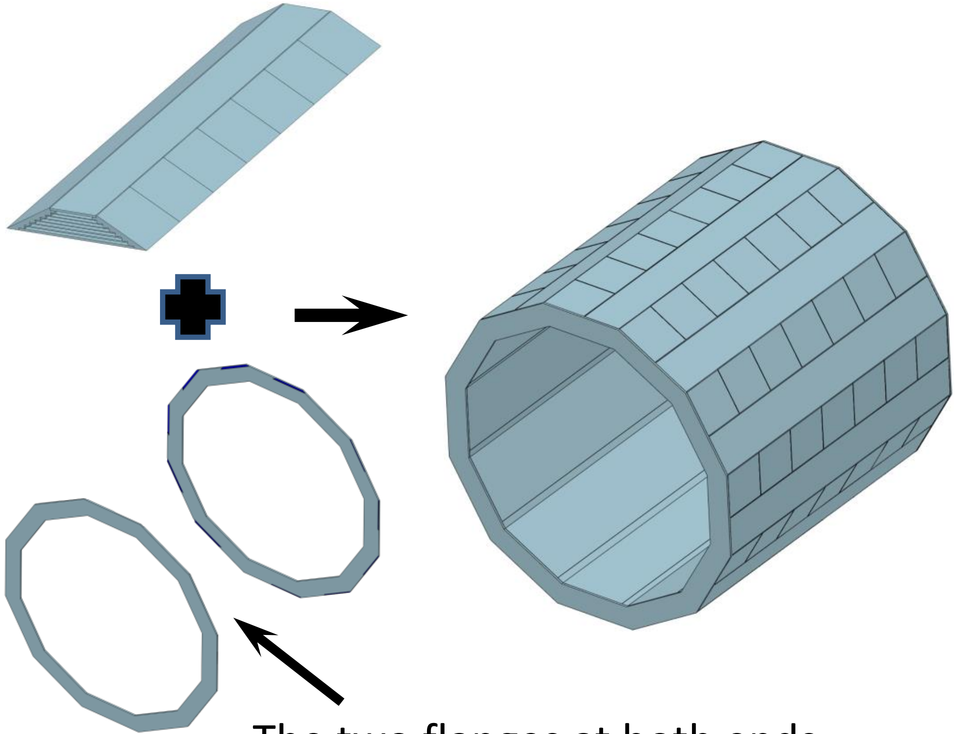
1. Installation steps are complex
   Assembly must be possible with the help of the auxiliary tooling
2. Every step of the installation requires collimation
3. Installation process requires more space and time
4. **Uncontrollable installing accuracy**

Comparison and selection of different schemes

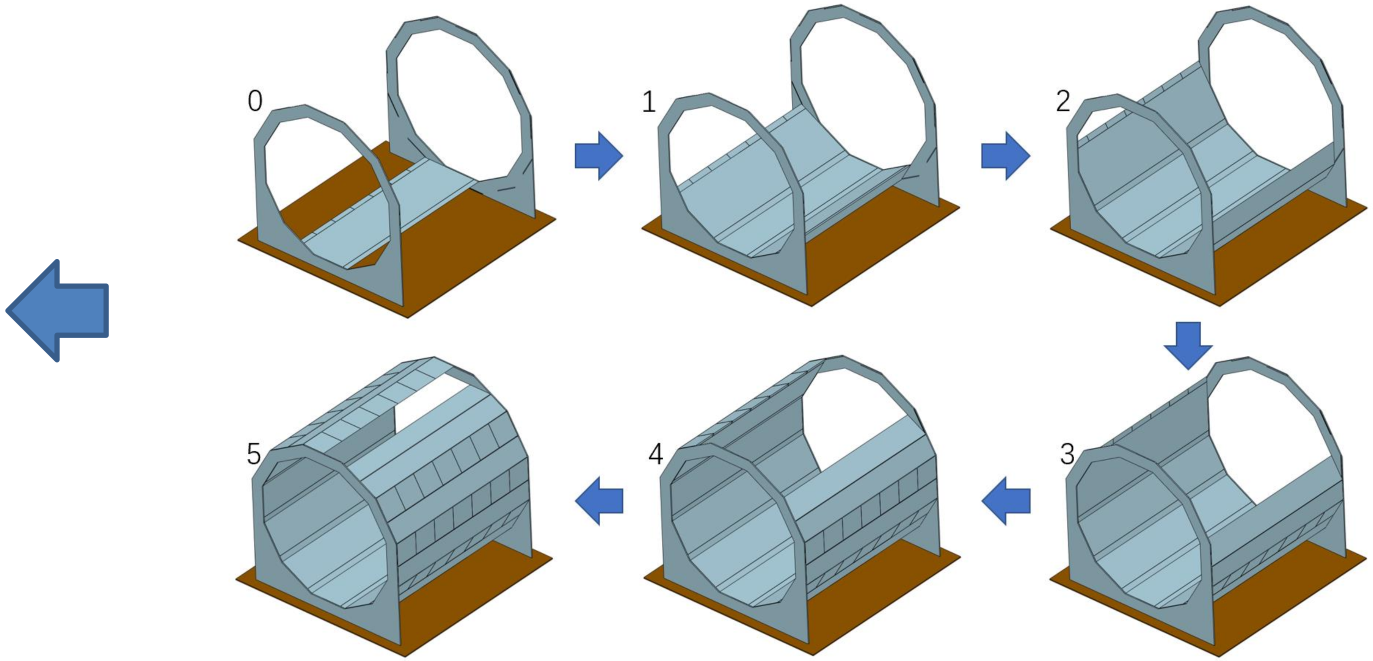
From the perspective of installation design :

Key : Different structural designs result in different installation designs

Scheme 2 : Self supporting structure



The two flanges at both ends are the installation tooling



The whole installation process, without any additional auxiliary tools.

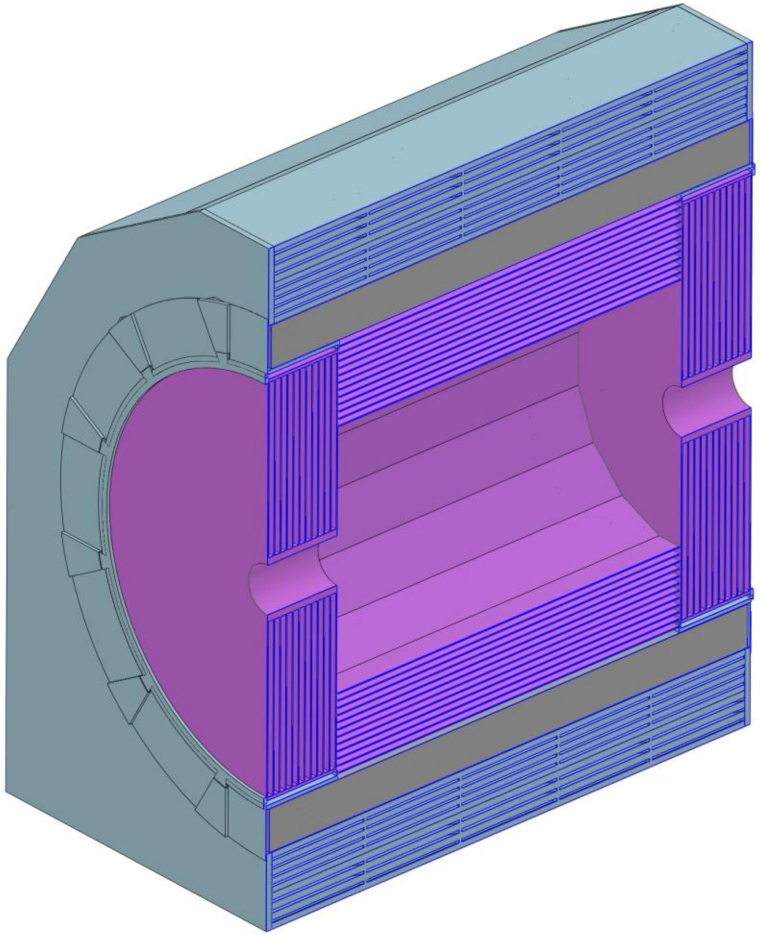
Overall installation concept design

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 concept design

1. Overall reliability and safety assessment



Simplified computational model

Key :

Deformation and stress of the Yoke and the connection structure

(Yes ? No)

As shown in the left figure:

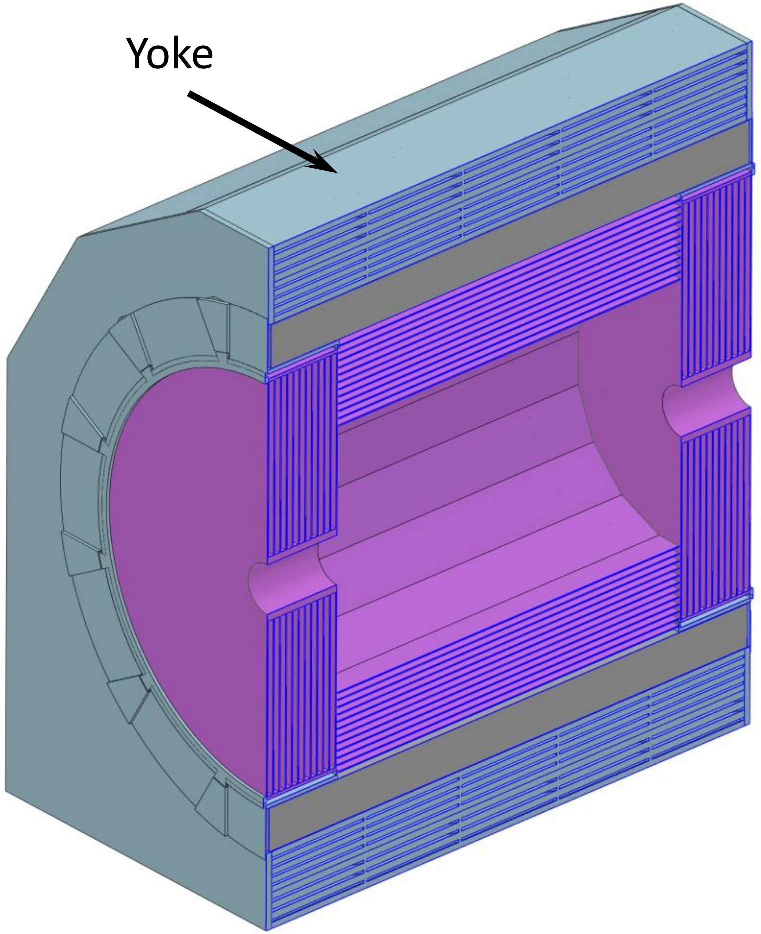
1. Simplified the simulated connection structure between the yoke, magnet and HCAL
2. Other lighter components are ignored

   These components do not affect the calculation results and overall assessment

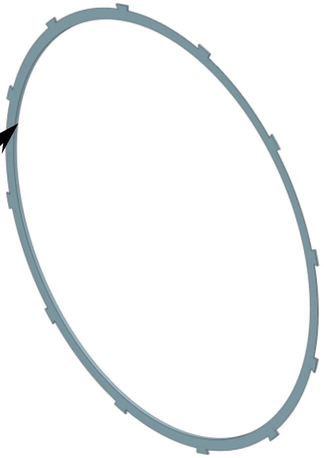
Overall installation concept design

1. Overall reliability and safety assessment

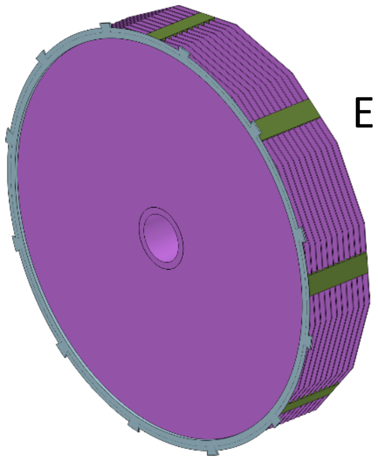
Yoke



Connection Ring

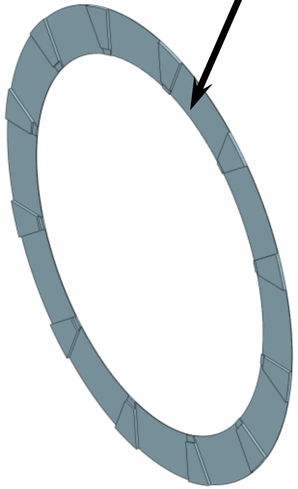


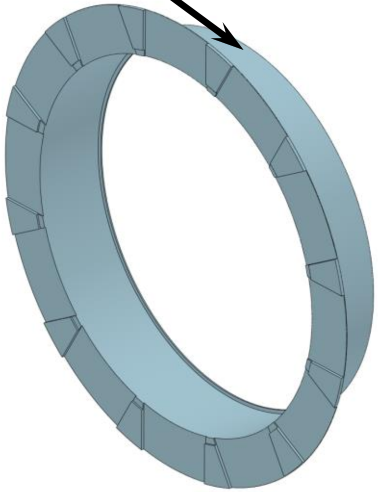
Rear end suspension

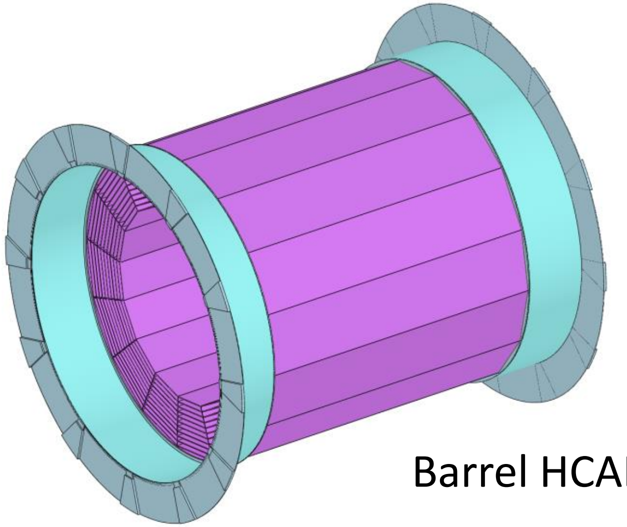


End HCAL

Connection Flange and Cylinder





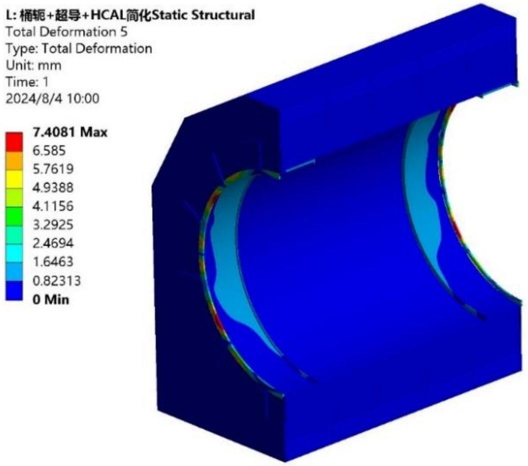


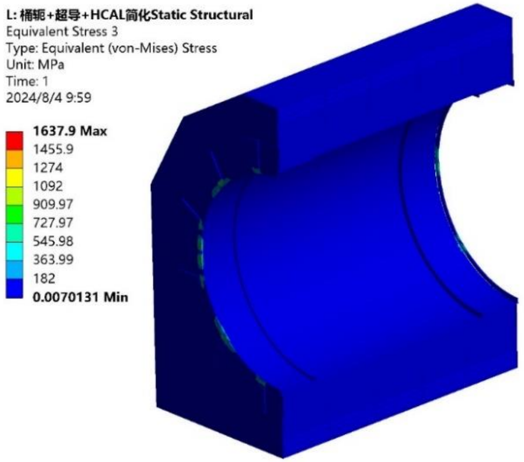
Barrel HCAL

Check Yoke, Ring, Flange, Cylinder

Overall installation concept design

1. Overall reliability and safety assessment





It's safety

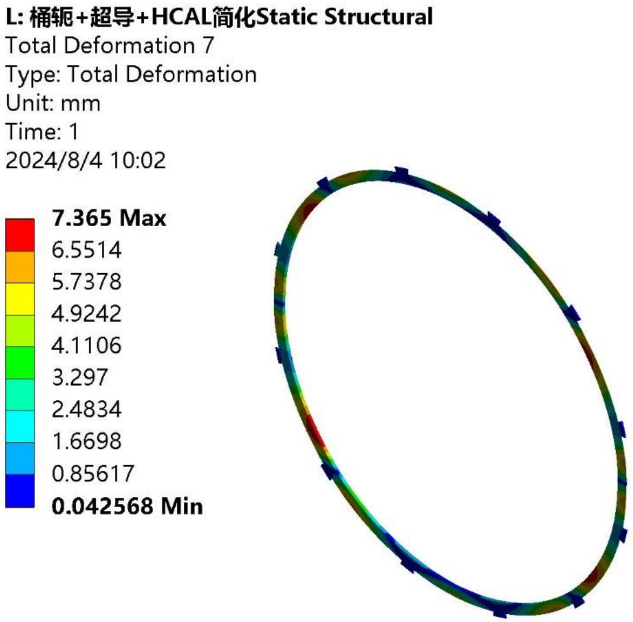
Deformation :

≈ 7.37

Stress :

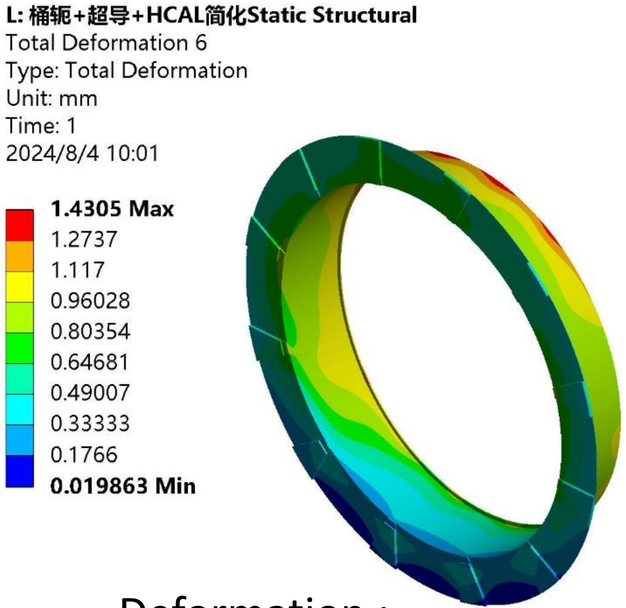
≈ 1638 MPa

In the middle of the two connections



Need improvement and optimization

(End HCAL)



Deformation :

≈ 1.43

Stress :

≈ 40.9 MPa

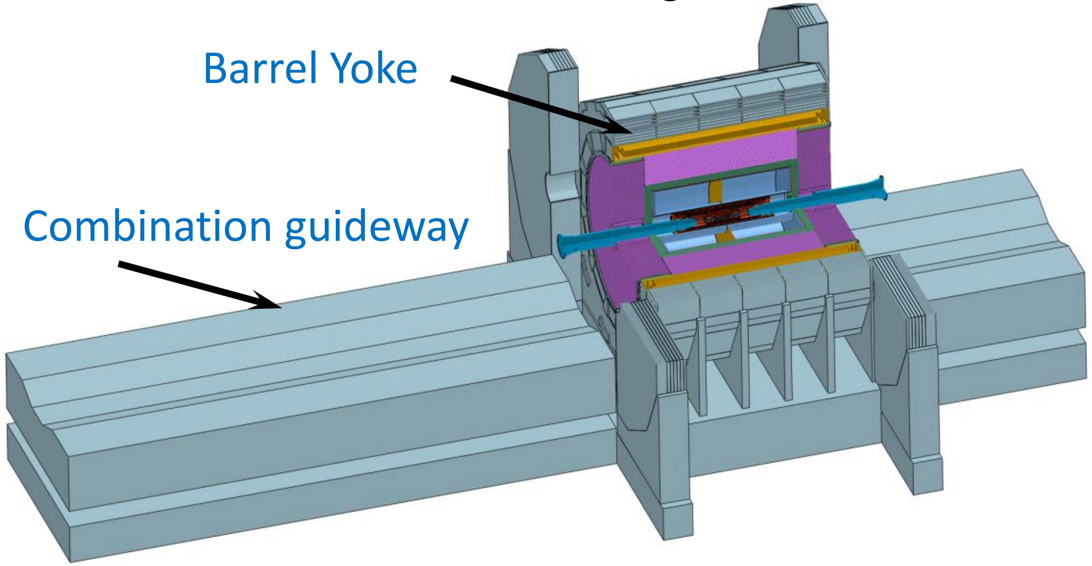
Overall installation concept design

2. Overall installation steps

Note :

Combination guideway is the installation reference, and is pre-aligned with yoke

General installation drawing



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 room through vertical shaft in sequence

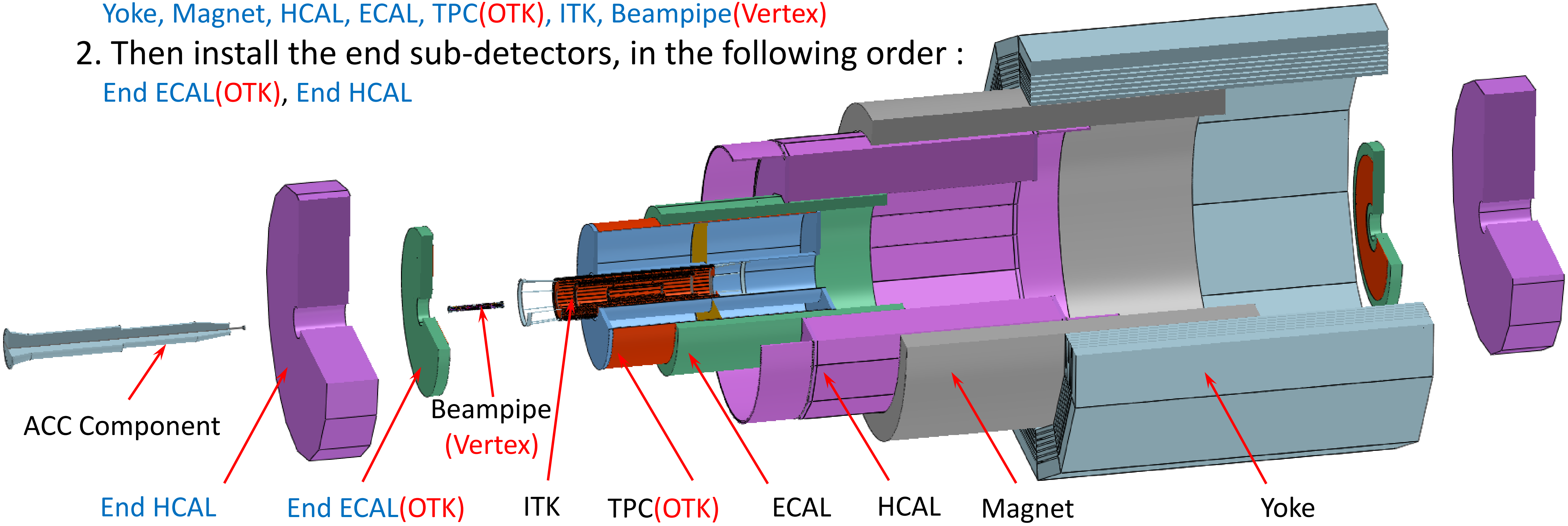
3. In the underground experimental room

Assembly the sub-detectors combination guideway and push them into the yoke in sequence

Overall installation concept design

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

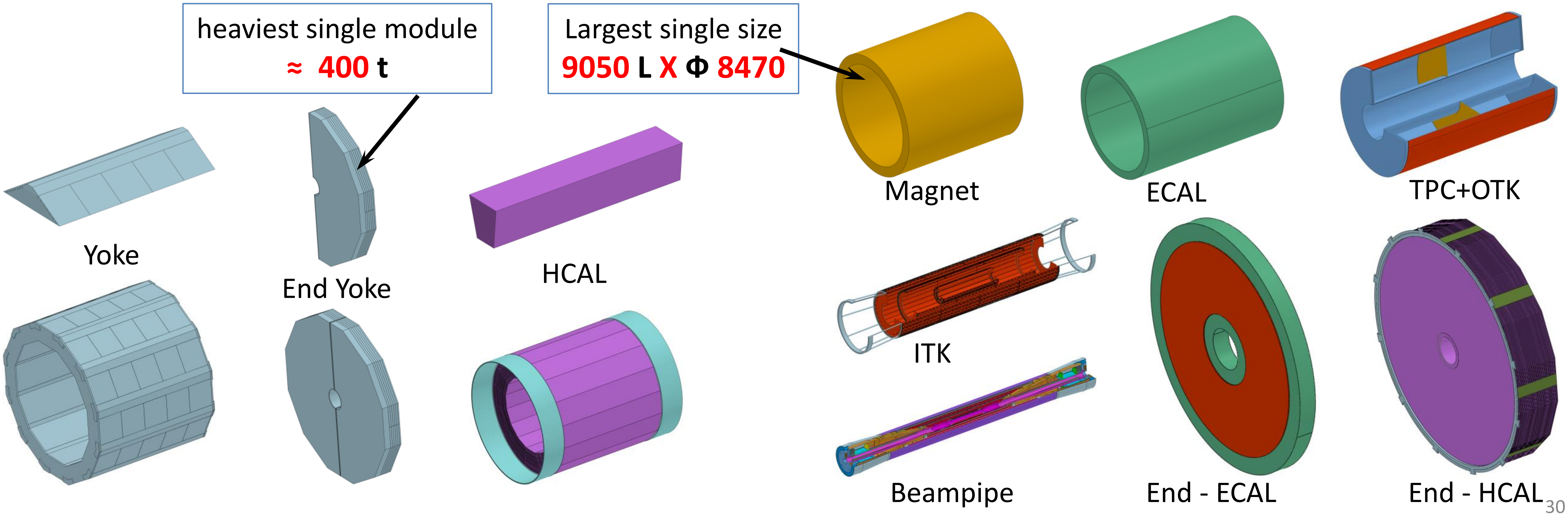
1. Install the barrel sub-detector first, in the following order :
   Yoke, Magnet, HCAL, ECAL, TPC(OTK), ITK, Beampipe(Vertex)
2. Then install the end sub-detectors, in the following order :
   End ECAL(OTK), End HCAL



Overall installation concept design

4. Modular lifting and integral lifting of 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

University

Hunan University
University of South China
Southwest Jiaotong University

IHEP (5)

Ji Quan
Zhang JunSong
Fu JinYu
Pei YaTian
Hou ShaoJing

Such a team is able to undertake CEPC design tasks

Design units

Zhejiang University

Design team

Manufacturing units

CITIC Heavy Industry

Future planning and visioning :

1. Allocate more mechanical engineers to join CEPC R&D as needed
2. There are many cooperative units in conventional fields, but CEPC requires cooperation in special fields
3. We will also seek international cooperation

Summary and working plan

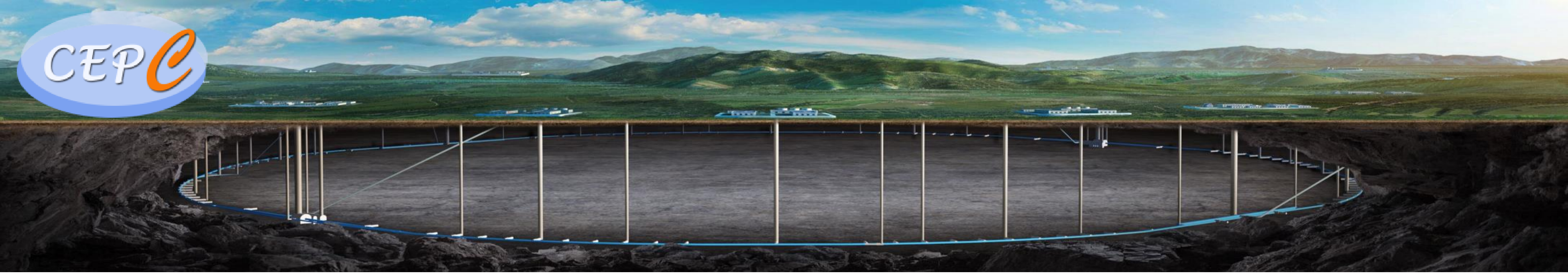
Summary

1. Supporting frame structure has been preliminary designed of each sub-detectors
2. The top-level installation design is basically completed, 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 layout of the underground experimental room and its auxiliary room (as soon as possible)
3. Complete the layout of the ground room



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