



Yoke Progress of CEPC Detector

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(IHEP)

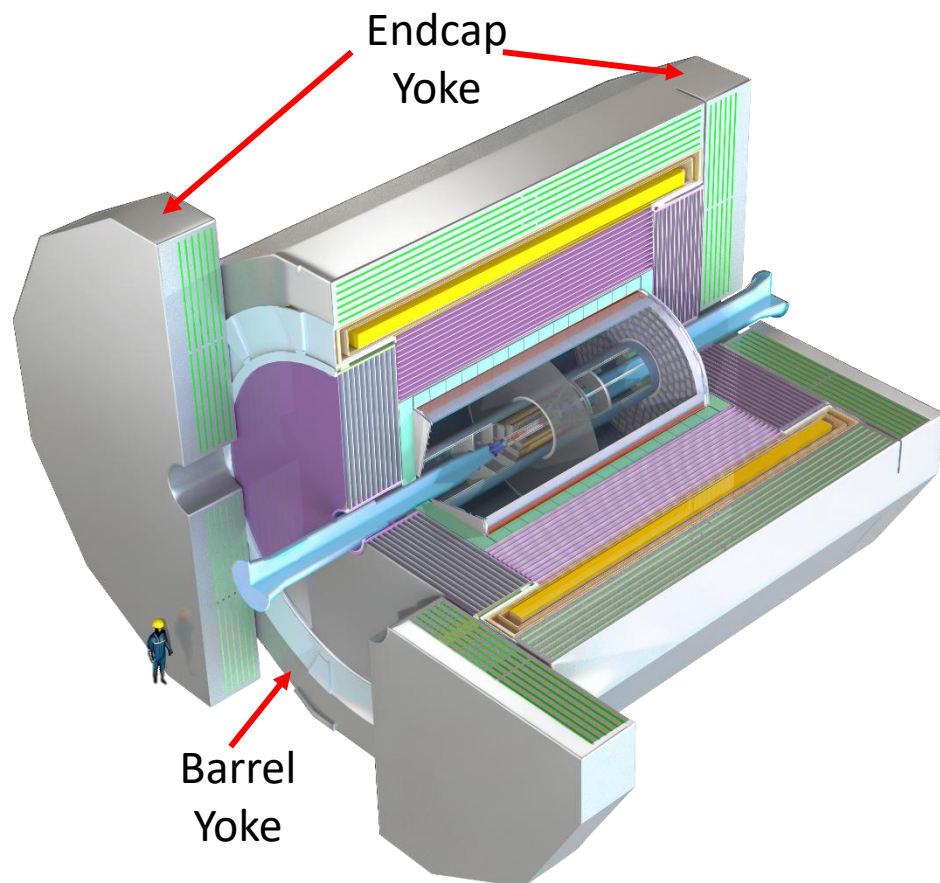


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Chinese Academy of Sciences

Outline

- Requirements
- Barrel yoke design
- Endcap yoke design
- Interface

Requirements



Functions

- 1) Provide support, adjustment and locking for the sub-detectors
- 2) Provide the magnetic field loop for magnet
- 3) Absorb all particles except muons
- 4) Provide placing space for muon detectors

Requirements

Muon detector requirements

- 1) Need 6 layers of muon detector
- 2) Each layer of muon detector needs 40 mm thickness space
- 3) Need as few detection dead zones as possible

Magnet requirements

- 1) Yoke material must have high permeability and small coercive force
- 2) Yoke structure requires the minimum magnetic leakage

Mechanical requirements

◆ Barrel yoke

- 1) Ensure sufficient strength and stiffness (gravity & electro-magnetic force)
- 2) Need a quick installation
- 3) Provide convenience for the maintenance of sub-detector

◆ Endcap yoke

- 1) Ensure sufficient strength and stiffness (gravity & electro-magnetic force)
- 2) Need a quick installation

Barrel yoke design

Modular design

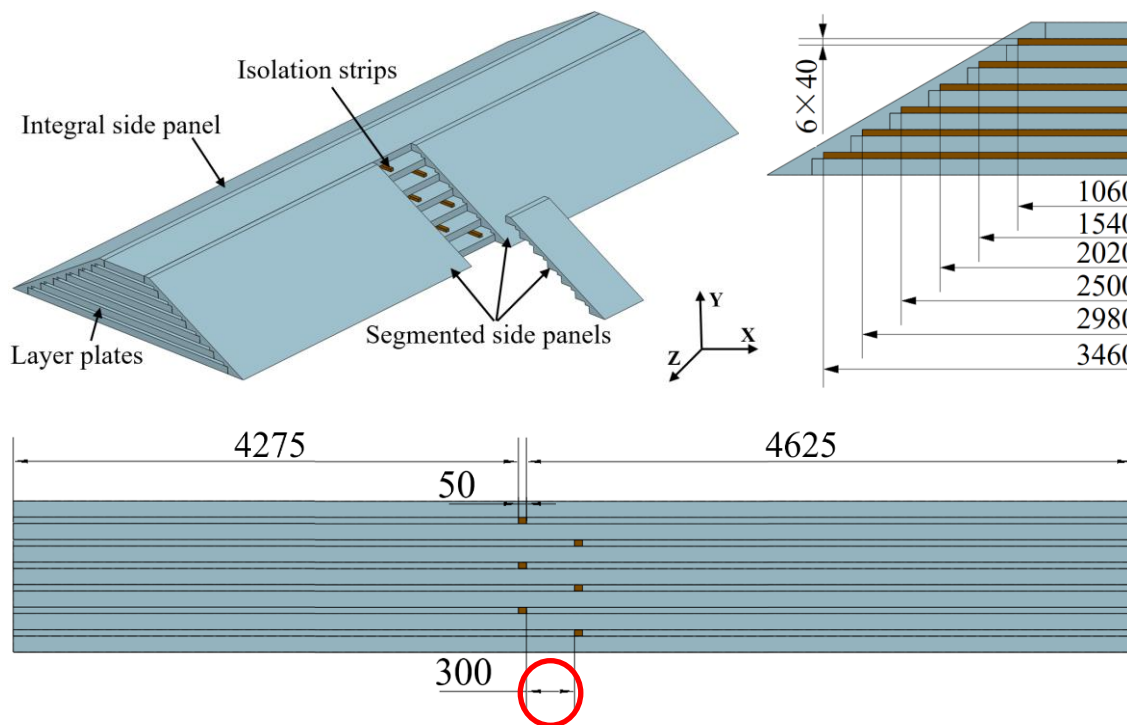
12 modules

Material: 10# steel

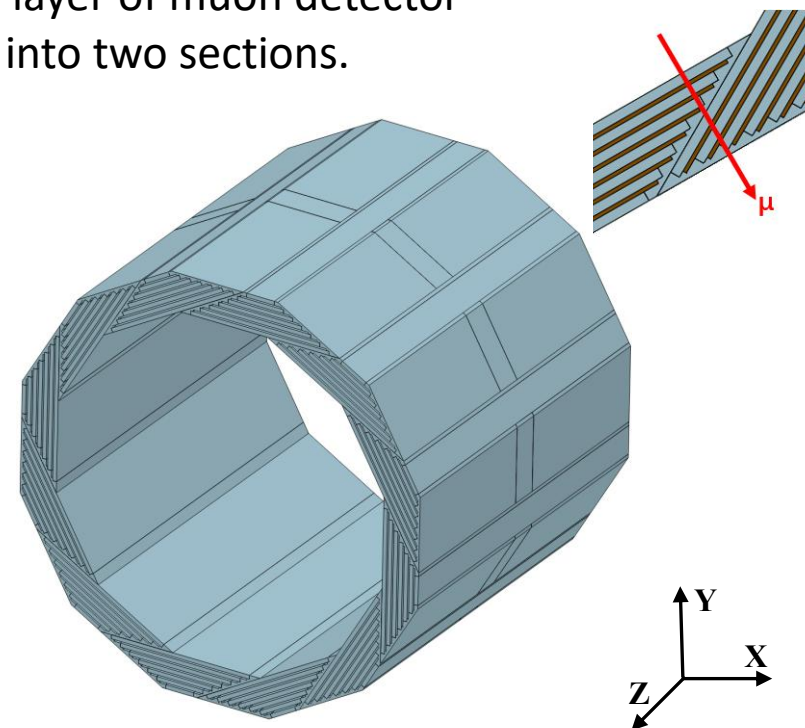
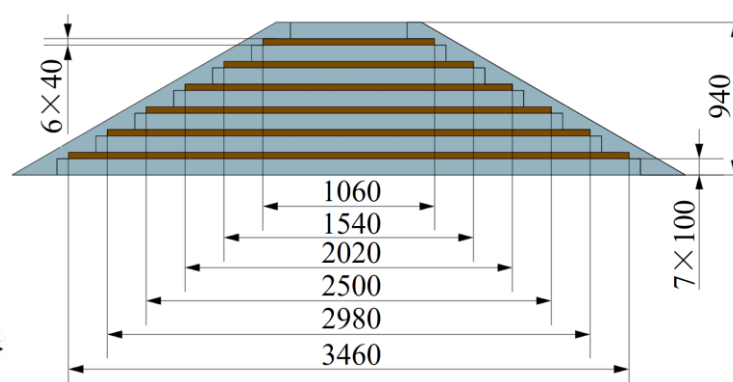
Weight: 1560t (130t×12)

Magnet requirement——each layer plate's thickness is 100 mm.

Muon detector requirement——each layer of muon detector space is 40 mm thickness and divided into two sections.



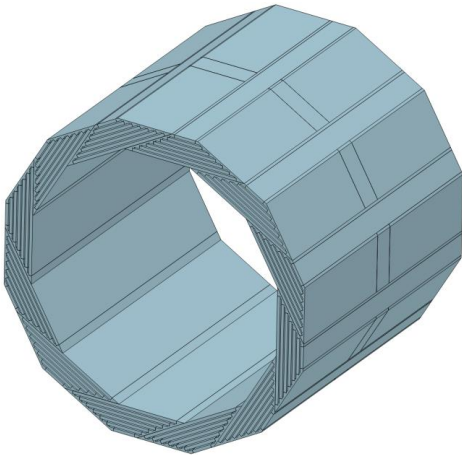
300 mm gap to avoid dead zone for muon detectors



Advantage

- 1) No detection dead zone between modules
- 2) Side panels can be opened separately to facilitate muon detector installation, cable management and maintenance

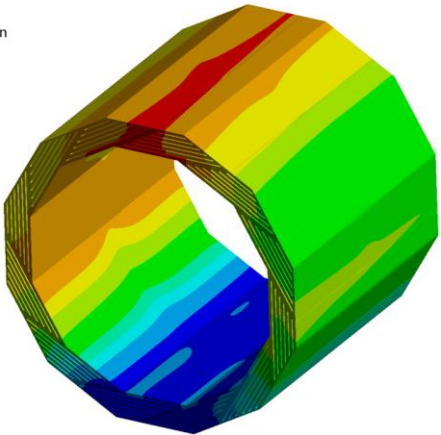
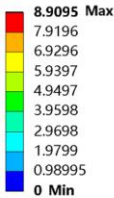
Barrel yoke design



Material parameters	
Material	10# steel
Density	7850kg/m ³
Elasticity modulus	206GPa
Poisson's ratio	0.3
Tensile Strength	335MPa
Yield strength	205MPa
Allowable stress	136.7MPa
Constraint	Bottom
Connection	All bonded

Simulation settings

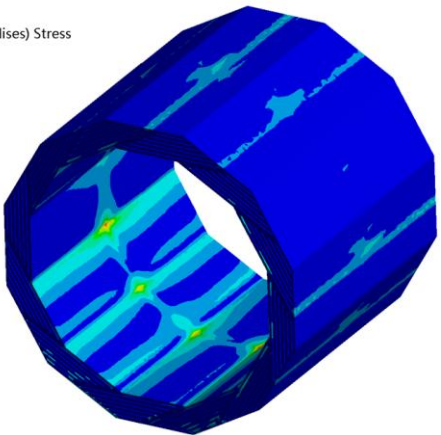
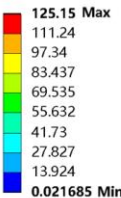
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1



Max deformation
8.9 mm

FEA result (gravity)

A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1



Max equivalent stress
125.2 MPa

Conclusion: Excessive deformation of the barrel yoke affects the positional accuracy of the sub-detectors, leading to a decrease in the detection accuracy of the sub-detectors. Barrel yoke needs to be optimized.

Barrel yoke design

Traditional installation scheme

Internal support frame installation scheme

Disadvantage

- 1) The internal support frame has high manufacturing accuracy, high cost, low usage frequency and waste of resource.
- 2) Each barrel yoke module is installed, alignment and adjustment is required, and the assembly accuracy is uncontrollable.
- 3) After the barrel yoke is installed, the disassembly of the internal support frame will affect the assembly accuracy of the barrel yoke.



CMS barrel yoke installation



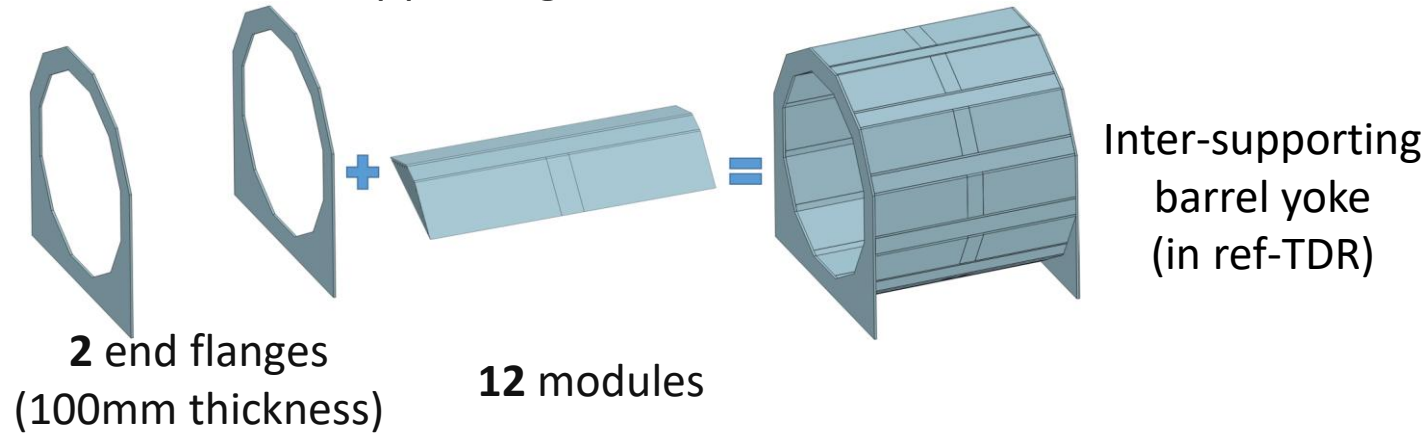
BESIII barrel yoke installation

Internal support frame

Barrel yoke design

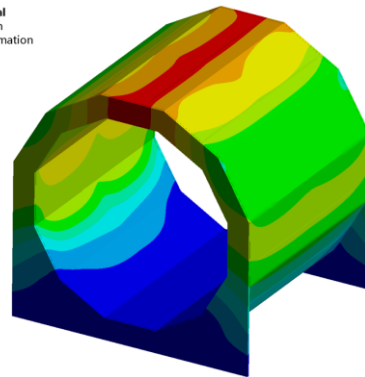
NEW installation scheme

Inter-supporting installation scheme



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1

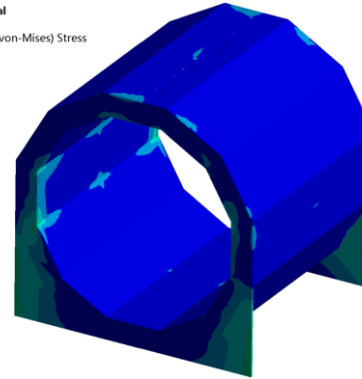
1.196 Max
1.0631
0.93021
0.79732
0.66443
0.53155
0.39866
0.26577
0.13289
0 Min



1.2 mm

A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1

63.38 Max
56.338
49.296
42.254
35.213
28.171
21.129
14.087
7.0452
0.0033 Min



63.4 MPa

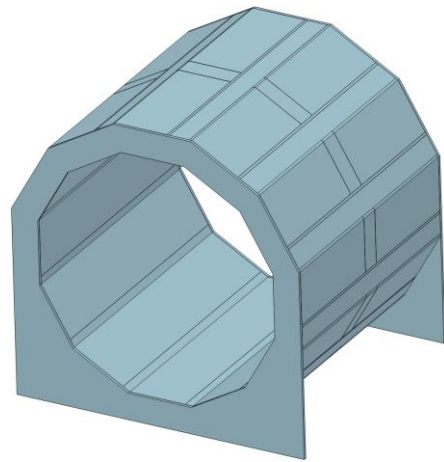
FEA result
(gravity)

Advantage

1) Using 2 end flanges to support the installation of barrel yoke module, the deformation and stress of barrel yoke are reduced

Barrel yoke design

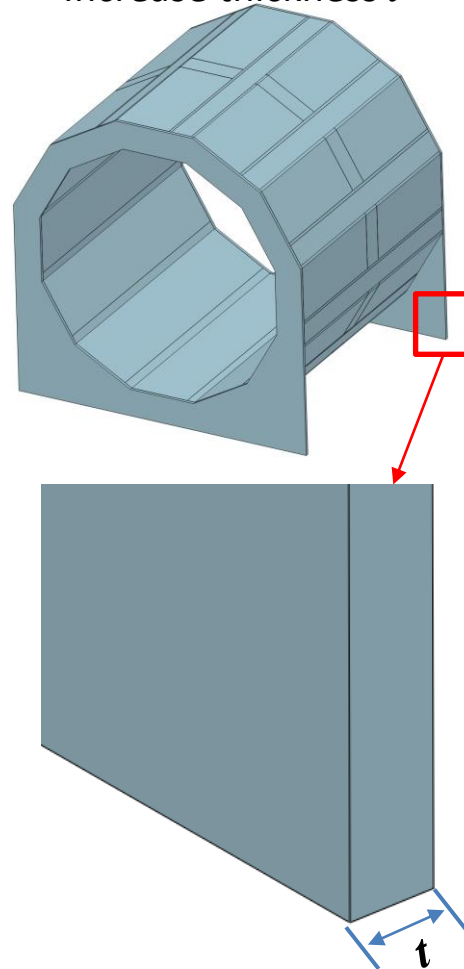
Optimization of end flange: Increase the bottom support area



Inter-supporting
barrel yoke

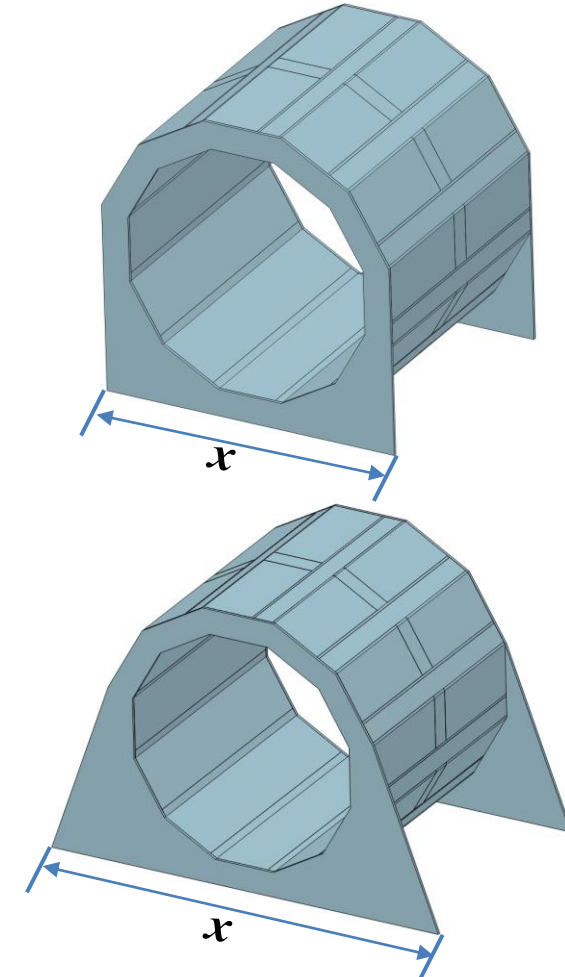
Optimization 1

Increase thickness t



Optimization 2

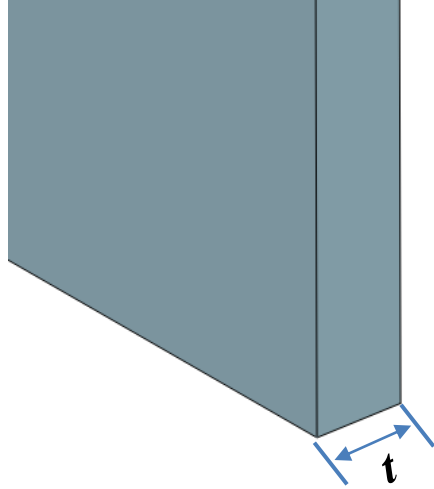
Increase bottom width x



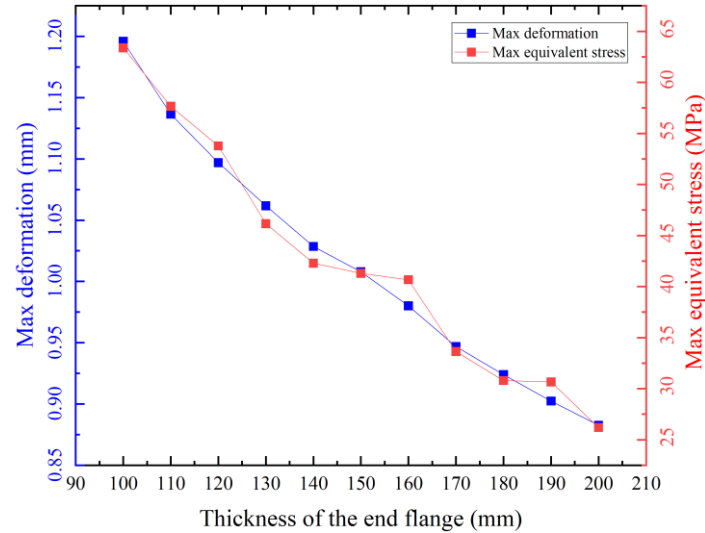
Barrel yoke design

Optimization 1

Increase thickness t



FEA result (gravity)



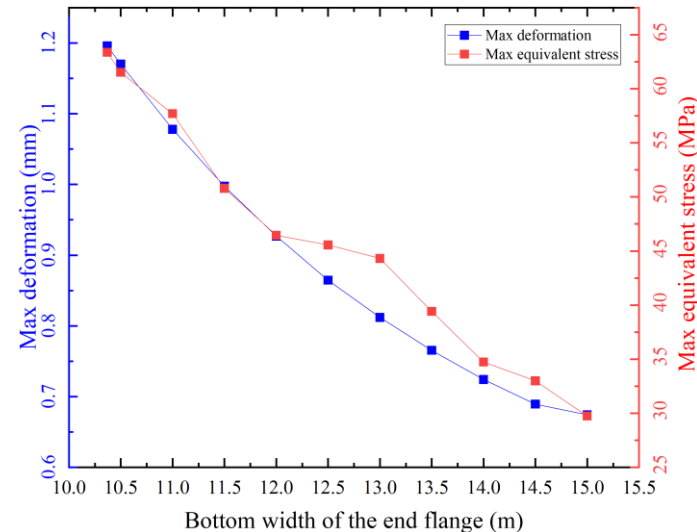
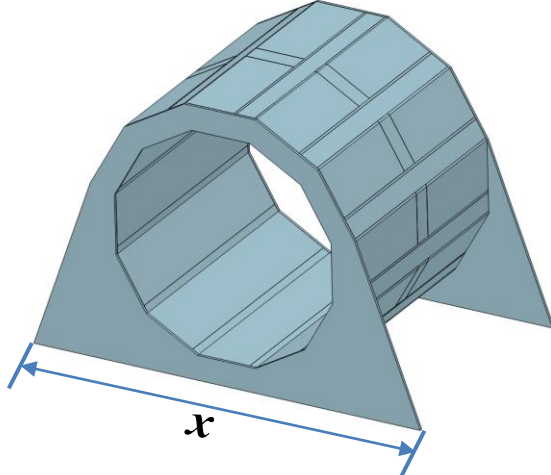
Result: As the thickness of the end flange increases, the maximum deformation and maximum equivalent stress of the barrel yoke under gravity load decrease.

Conclusion:

End flange has significant optimization potential. Various optimizations can be achieved by adjusting its thickness and the bottom width, all of which can further enhance the overall stiffness and strength of the barrel yoke.

Optimization 2

Increase bottom width x

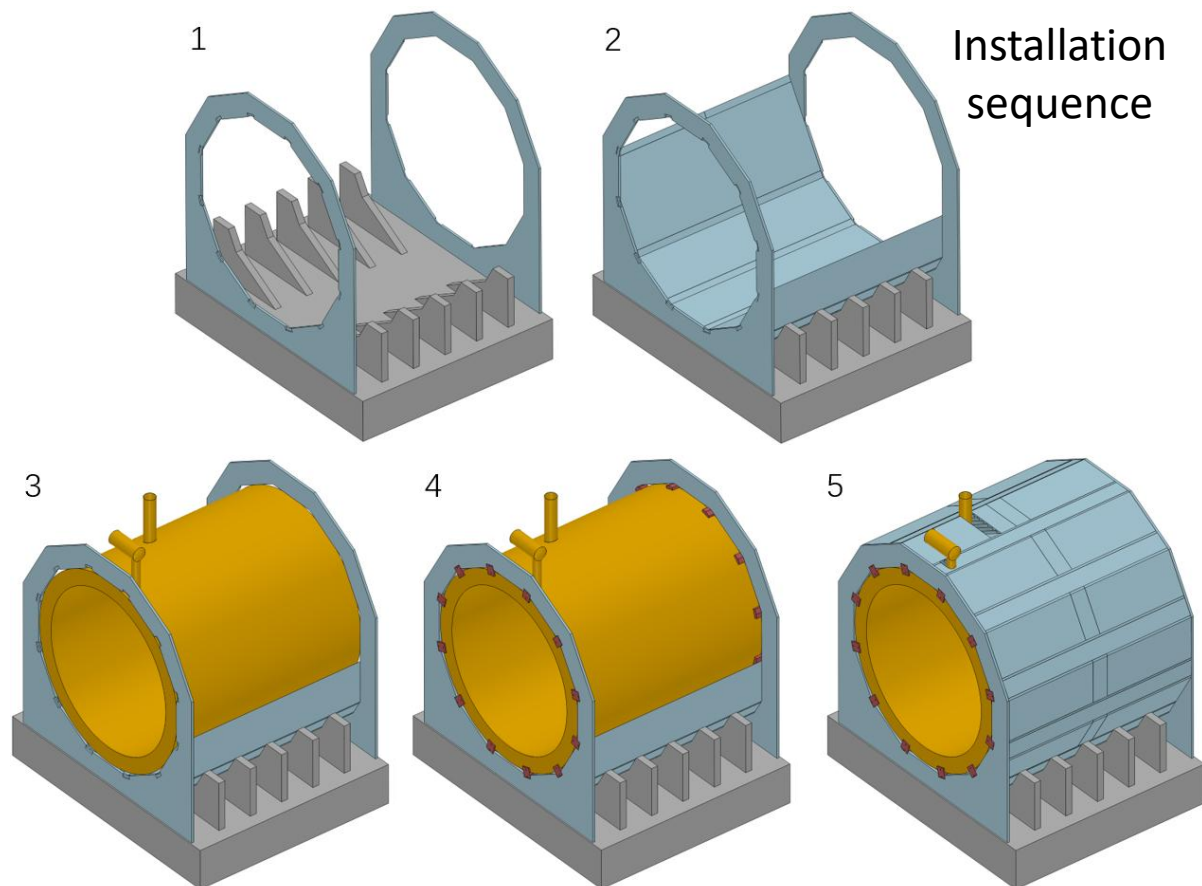
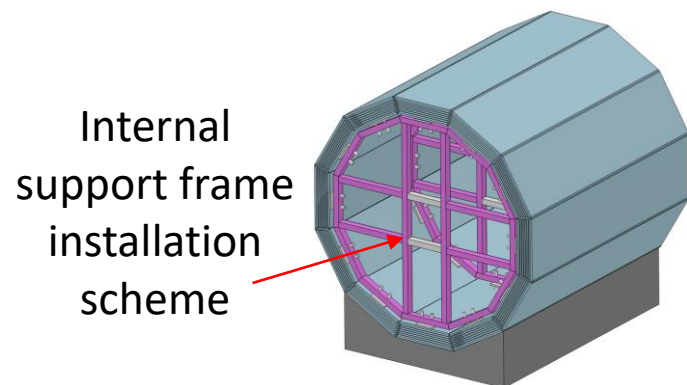


Result: As the bottom width of the end flange increases, the maximum deformation and maximum equivalent stress of the barrel yoke under gravity load decrease.

Barrel yoke design

NEW installation scheme

Inter-supporting installation scheme



1. Install the bottom 5 modules
2. Install the magnet.
3. Fix the magnet
4. Install the top 7 modules

Advantage

- 2) No internal support frame during barrel yoke installation, which is a quick installation.
- 3) Align and adjust the end flange, then install the module, which can ensure the controllability of assembly accuracy.

Barrel yoke design

Reliability and safety assessment

The whole detector is installed, barrel yoke has two loading conditions:
without and with electromagnetic force

Load

1.Yoke gravity

2.Sub-detector gravity

2145 tons in simulation

Magnet, barrel HCAL, barrel ECAL

endcap HCAL, endcap ECAL

barrel muon detectors

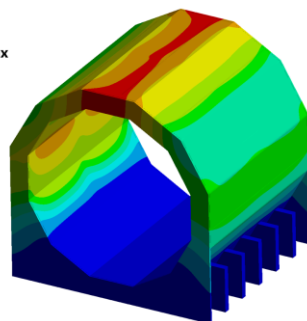
Ignore lighter detectors

3.Electromagnetic force

FEA result

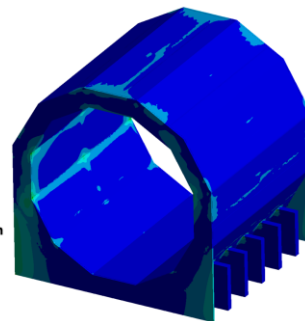
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1

1.84 Max
1.64
1.43
1.23
1.02
0.819
0.614
0.41
0.205
0 Min



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1

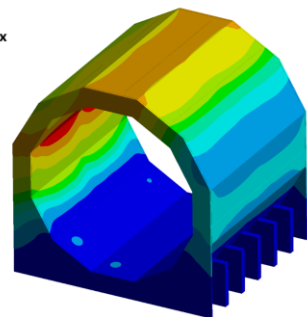
93.8 Max
83.3
72.9
62.5
52.1
41.7
31.3
20.8
10.4
4.44e-5 Min



Without electromagnetic force

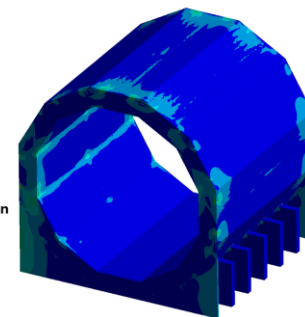
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1

2.18 Max
1.94
1.69
1.45
1.21
0.968
0.726
0.484
0.242
0 Min



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1

122.19 Max
108.62
95.039
81.463
67.887
54.311
40.734
27.158
13.582
0.005357 Min



With electromagnetic force

Conclusion:

(1) When all sub-detectors load is applied to the barrel yoke, the maximum deformation is 1.8 mm. The maximum stress is about 94 MPa, which is below the allowable stress, thereby meeting the design and safety requirement.

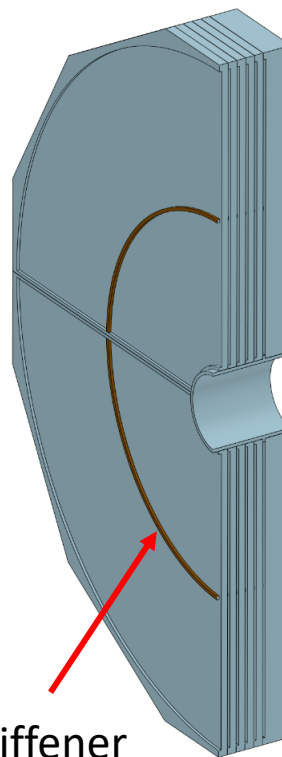
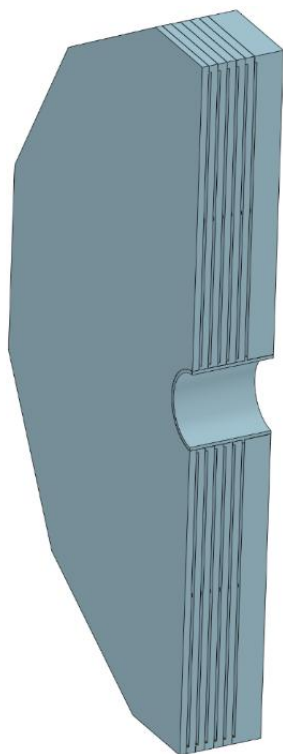
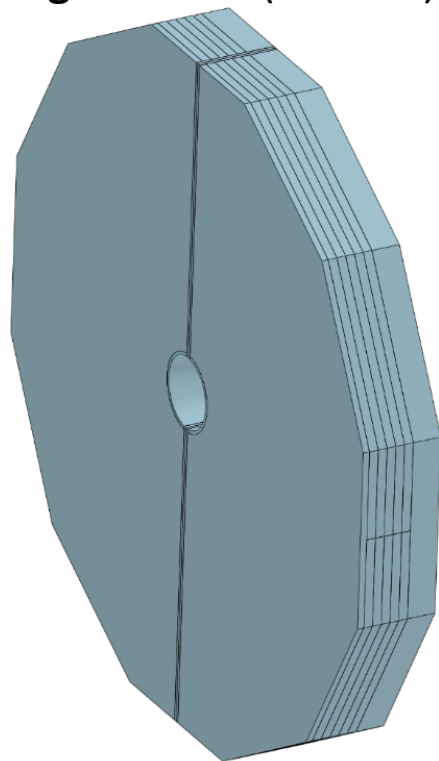
(2) When all sub-detectors are installed and subjected to electromagnetic force from magnet, the maximum deformation is 2.2 mm. The maximum stress is about 122 MPa, less than allowable stress, remaining within safe operational limits.

Endcap yoke design

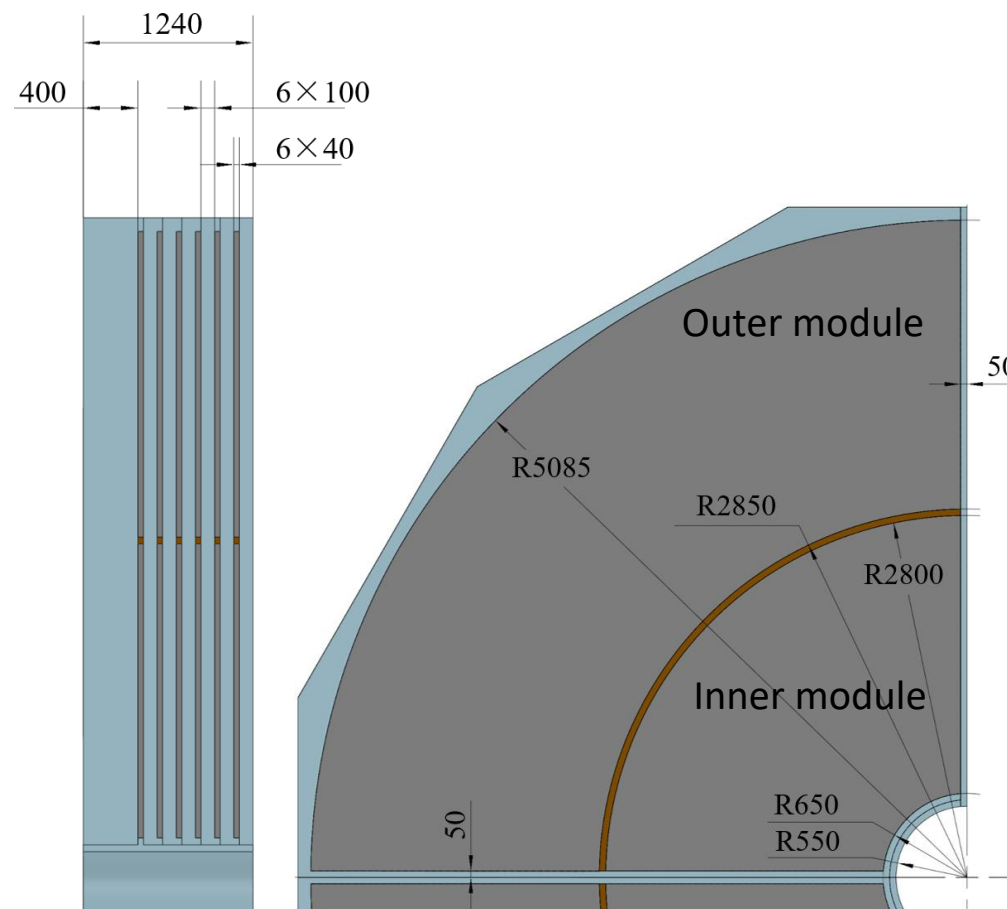
2 endcap yoke, 4 parts

Material: 10#

Weight: 1400t (700t×2)



Stiffener



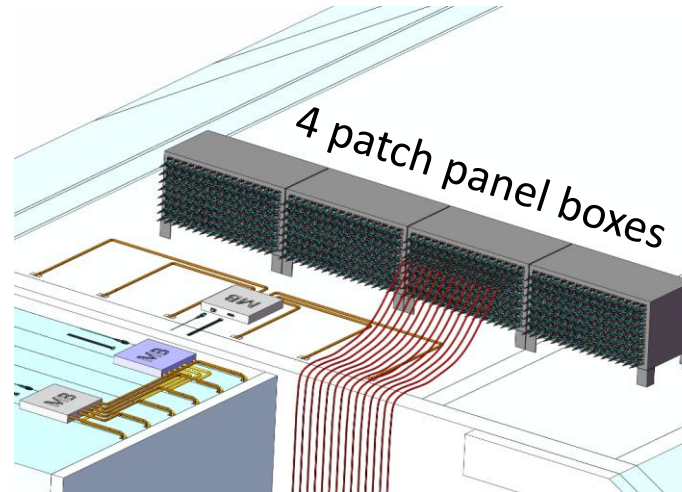
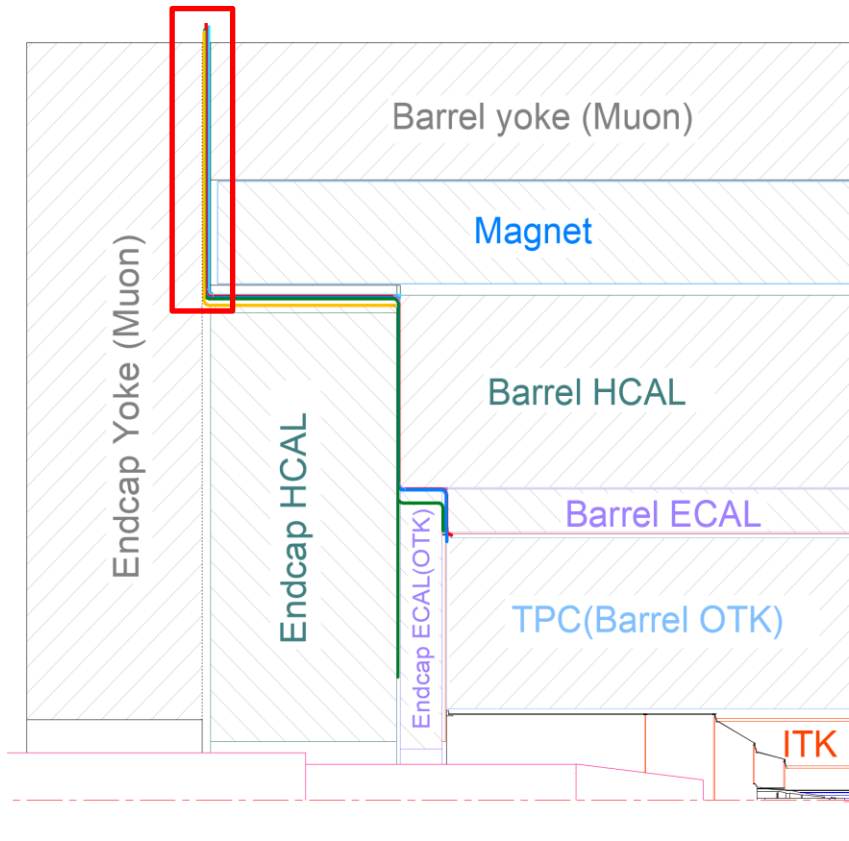
Advantage:

- 1) Modular design, has left and right halves.
- 2) Can be opened from the middle for easy maintenance of the sub-detectors in the barrel.

Interface

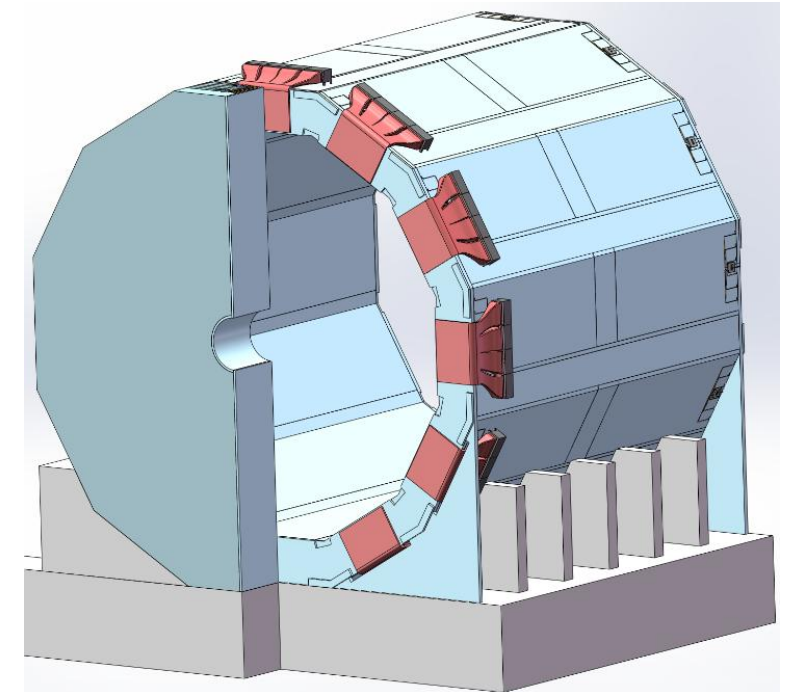
1) Cabling and piping of sub-detectors

60mm clearance
for all sub-detectors' cables and pipes



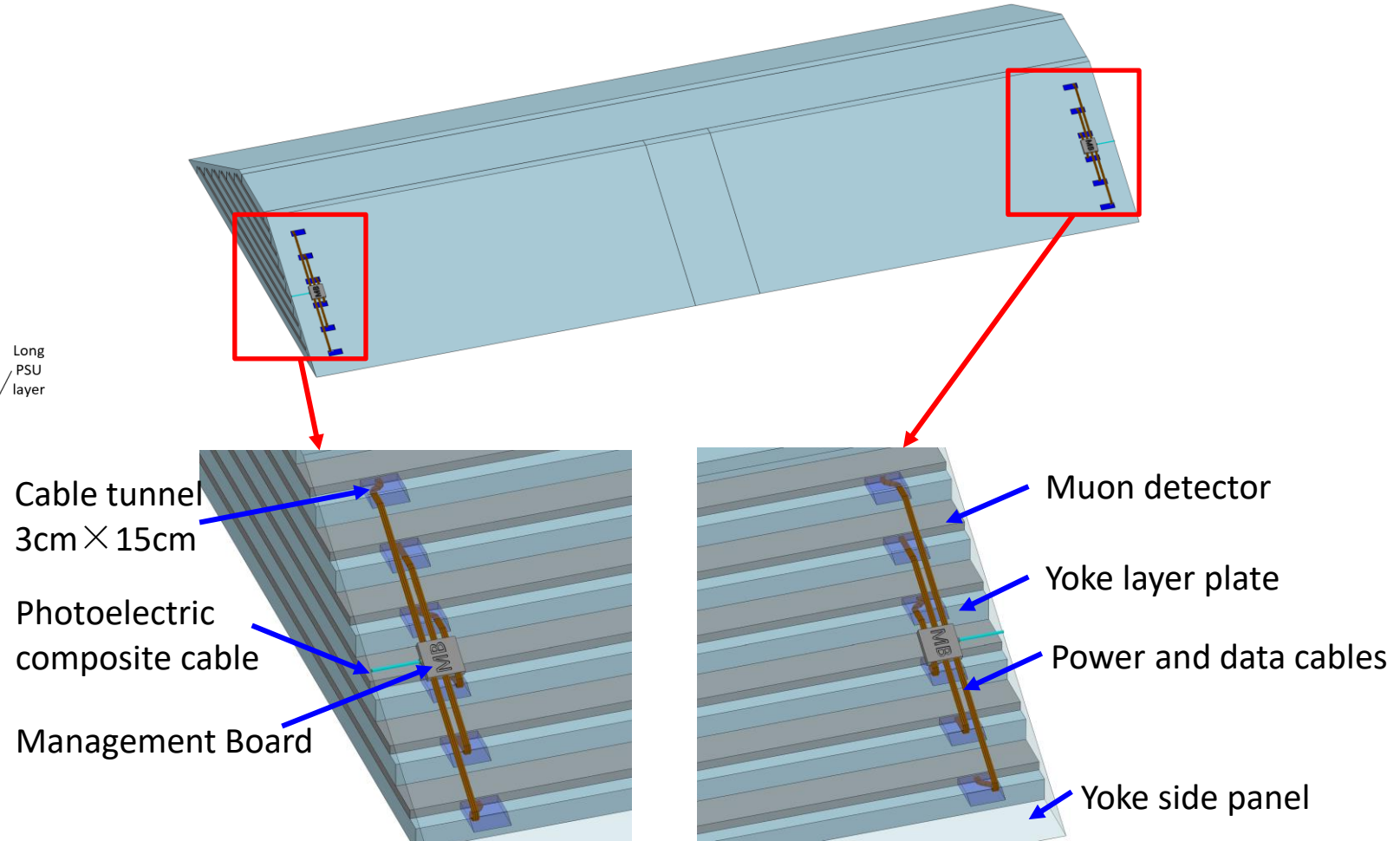
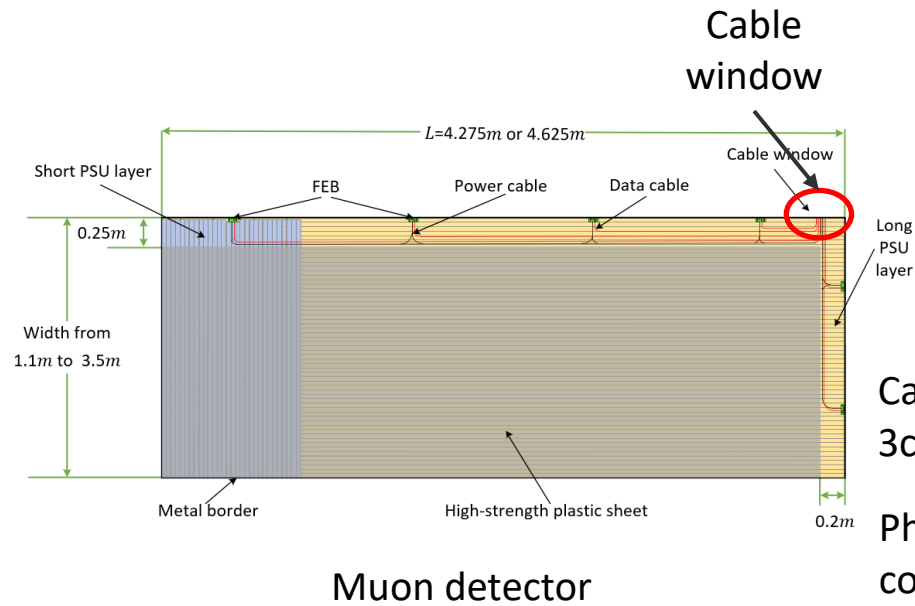
Cables and pipes from the clearance and is connected to 4 patch panel boxes on the outside of the barrel yoke module

44 patch panel boxes
(One side)



Interface

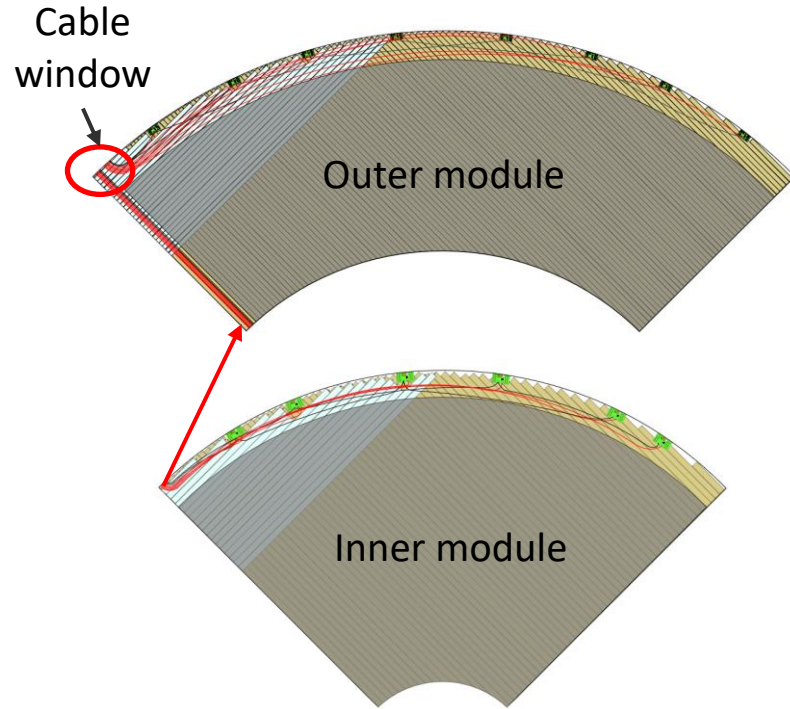
2) Cables of barrel muon detectors



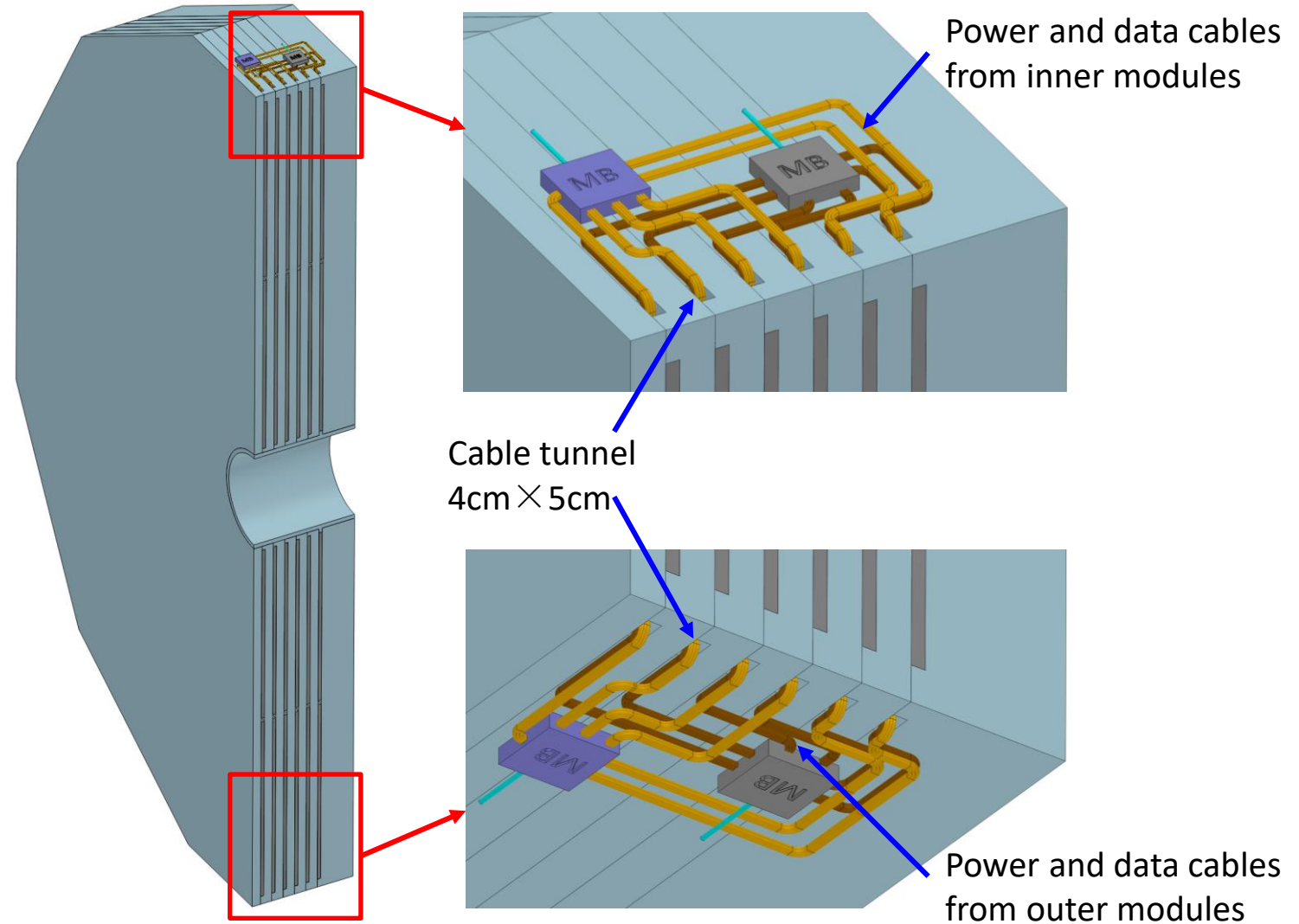
Cables are led out from the side. Cable tunnels (square holes) are set at the corresponding positions on the side panels of the barrel yoke module.

Interface

3) Cables of endcap muon detectors

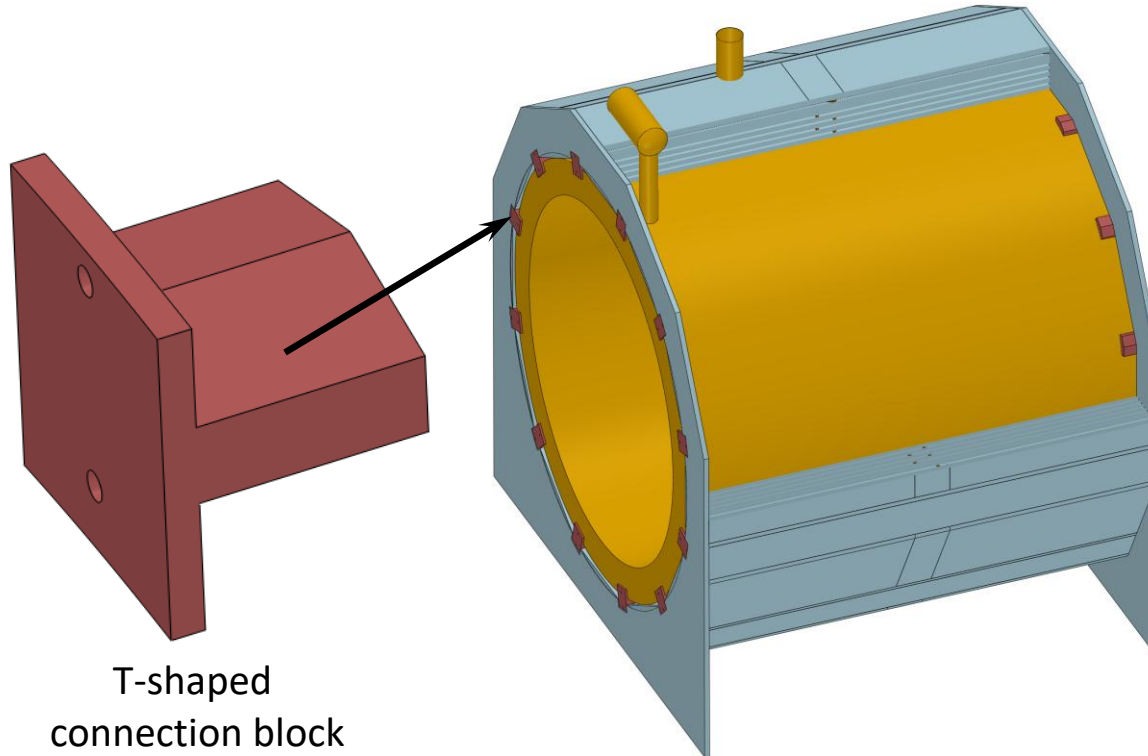


Cables are led out from top and bottom of endcap yoke.

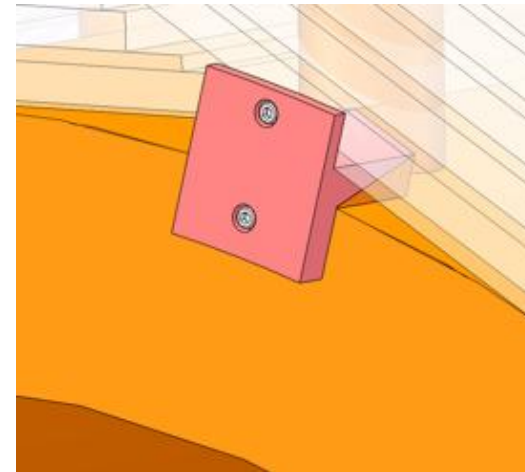


Interface

4) Connection of magnet



T-shaped
connection block

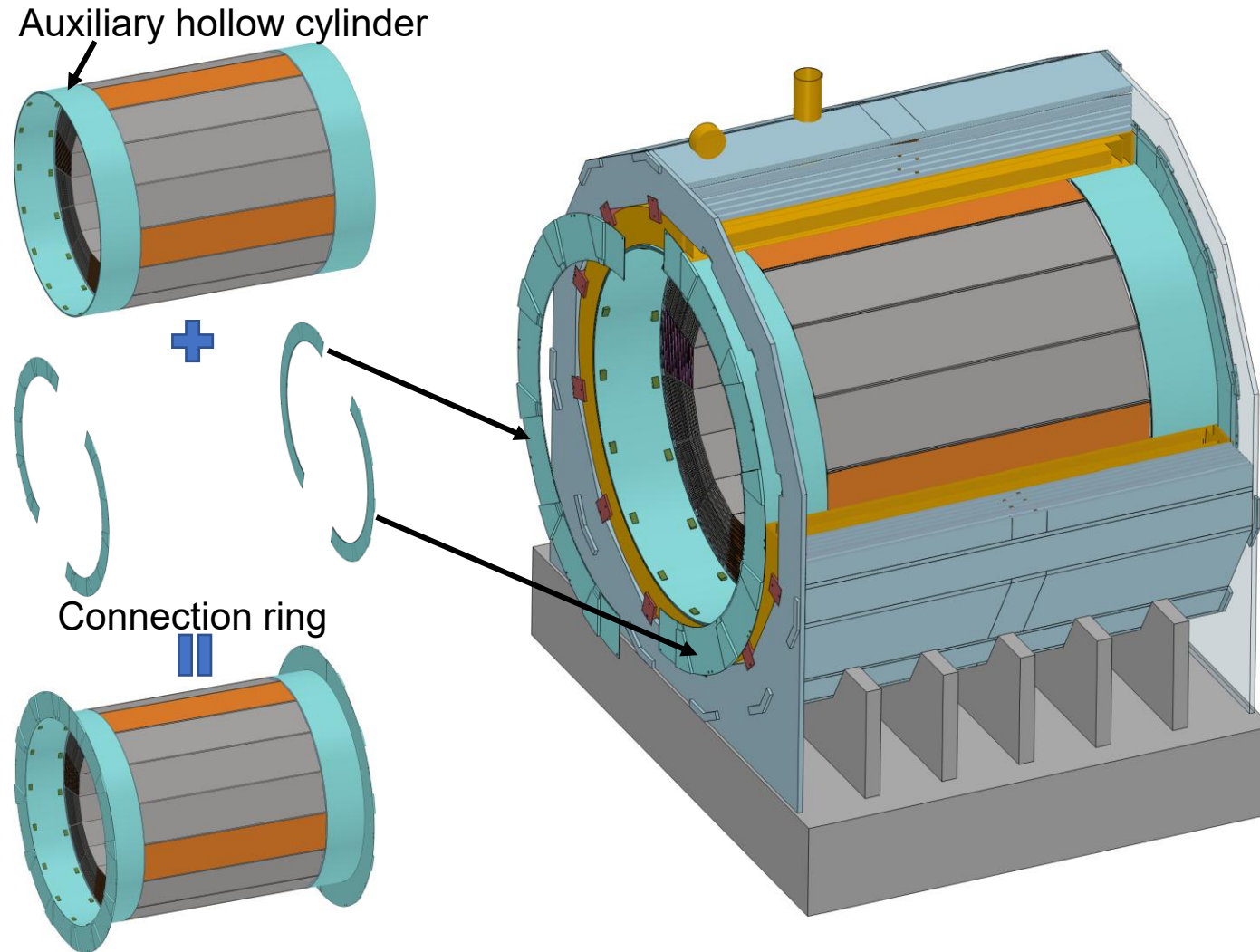


Connect the end flange
and the magnet with screws

The magnet is connected to the barrel yoke's end flange by 12 T-shaped connection blocks placed in the triangular spaces between yoke polygons and the magnet ring.

Interface

5) Connection of barrel HCAL



2 connection ring for connecting the auxiliary hollow cylinder of the barrel HCAL and the end flange of the barrel yoke.

Summary

- Yoke is the start for the installation of all sub-detector and the foundation for the safe and reliable operation of all sub-detectors.
- The barrel yoke is proposed to have a inter-supporting structure, which is different from the traditional design of the barrel yoke. Although it has many advantages, further research are still needed.
- The cables and pipes of sub-detectors come out from the clearance. Due to the excessive number of cables, further optimization design is still required. And the connection related to the barrel yoke also needs to be optimized.

Thanks!