CEPC MDI Detector Issues

--- In engineering design

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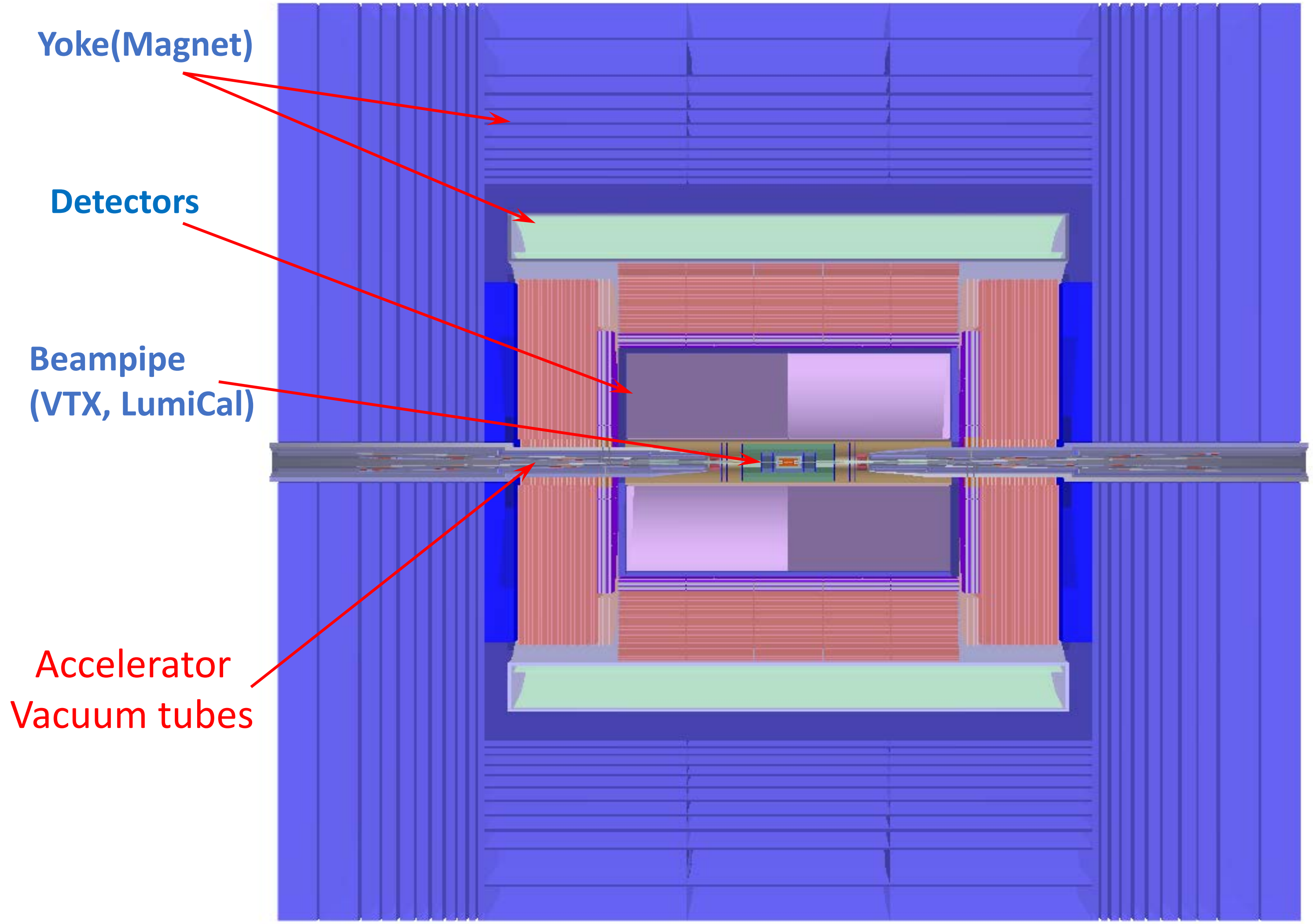
Jan 16,2020

Contents:

1. General introduction

1) Composition of the spectrometer (In CDR)



From outside to inside:

Yoke(Magnet) --- in design

Detectors

- Muon detector
- Hadronic calorimeter
- Electromagnetic calorimeter
- Silicon external tracker
- Time Projection Chamber
- Silicon Inner Tracker

Beampipe(VTX,LuniCal) --- in design

General requirement：

On the premise of meeting the physical requirements of the experiment, the sealed connection between the accelerator vacuum tube and the beam pipe is realized

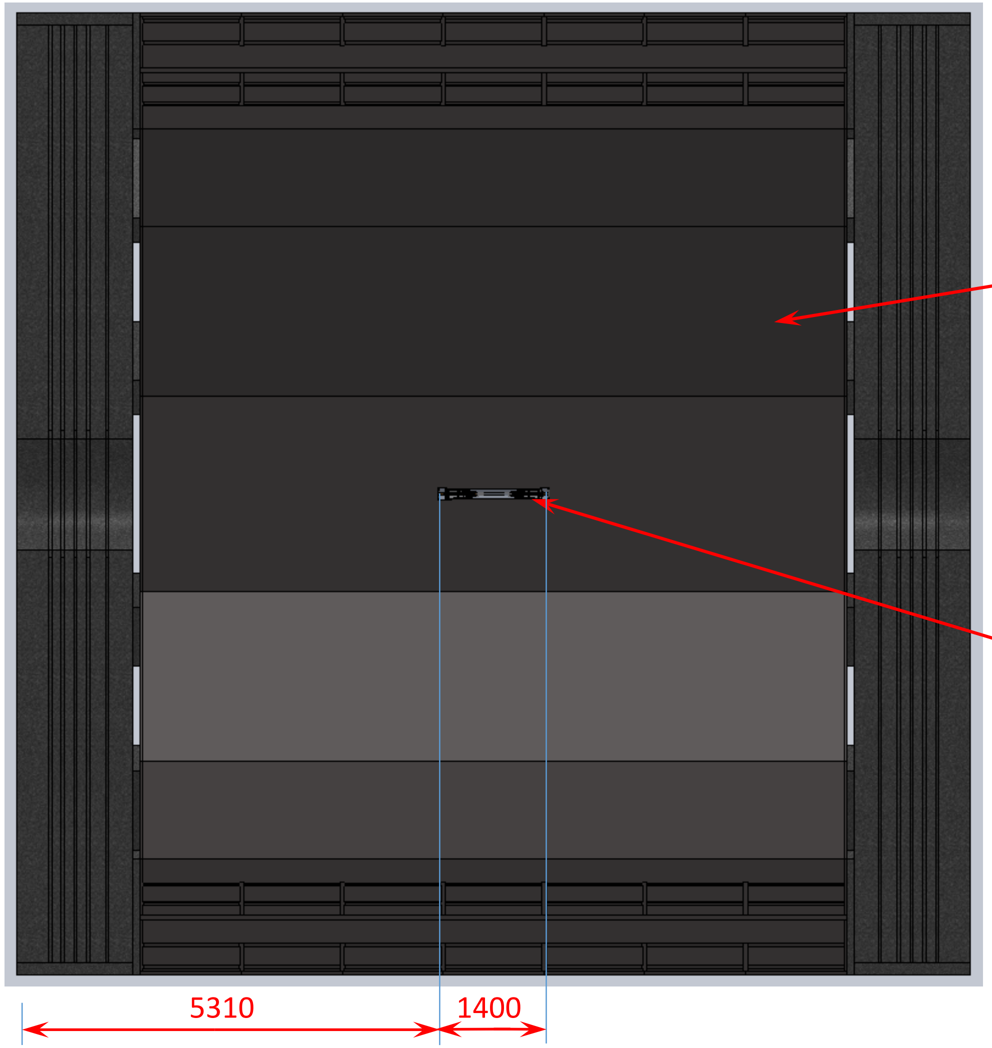
The connection part between spectrometer and accelerator is accelerator vacuum tube

2) Design requirements

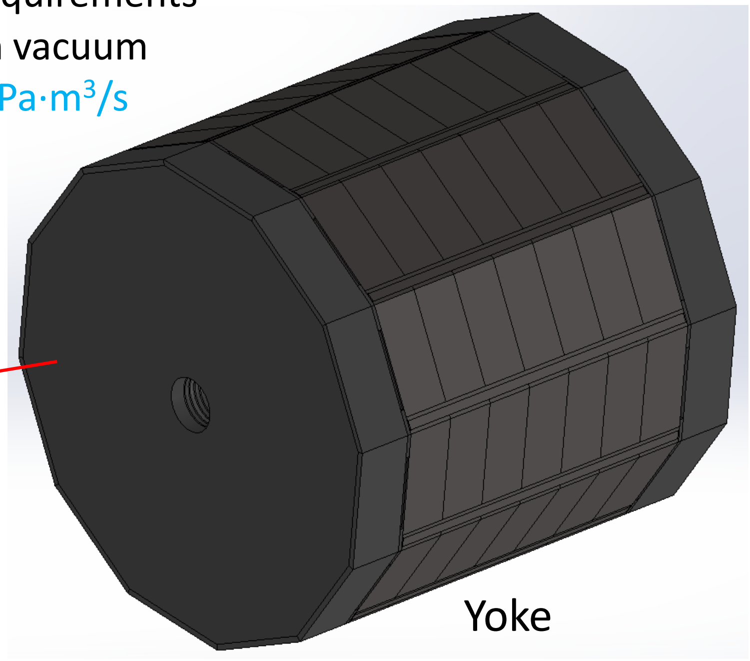
a. No interference with the spectrometer and accelerator tube

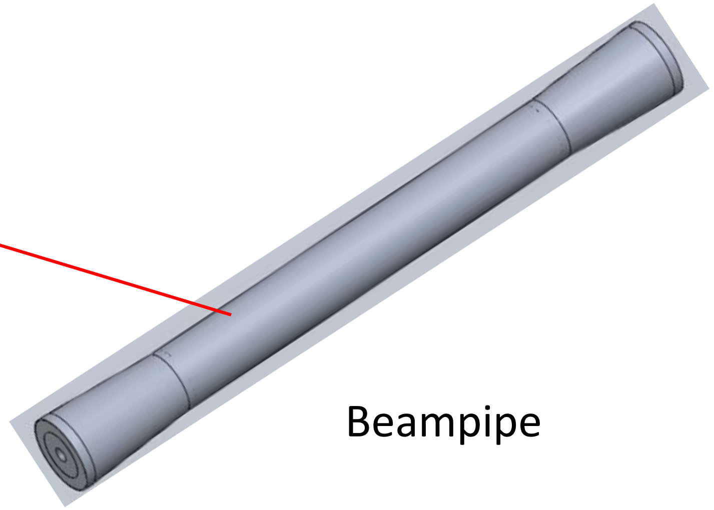
b. The accelerator vacuum tube is connected with the beampipe easily and reliably

c. Meet the requirements of ultra-high vacuum $2.66X10^{-11}Pa \cdot m^3/s$



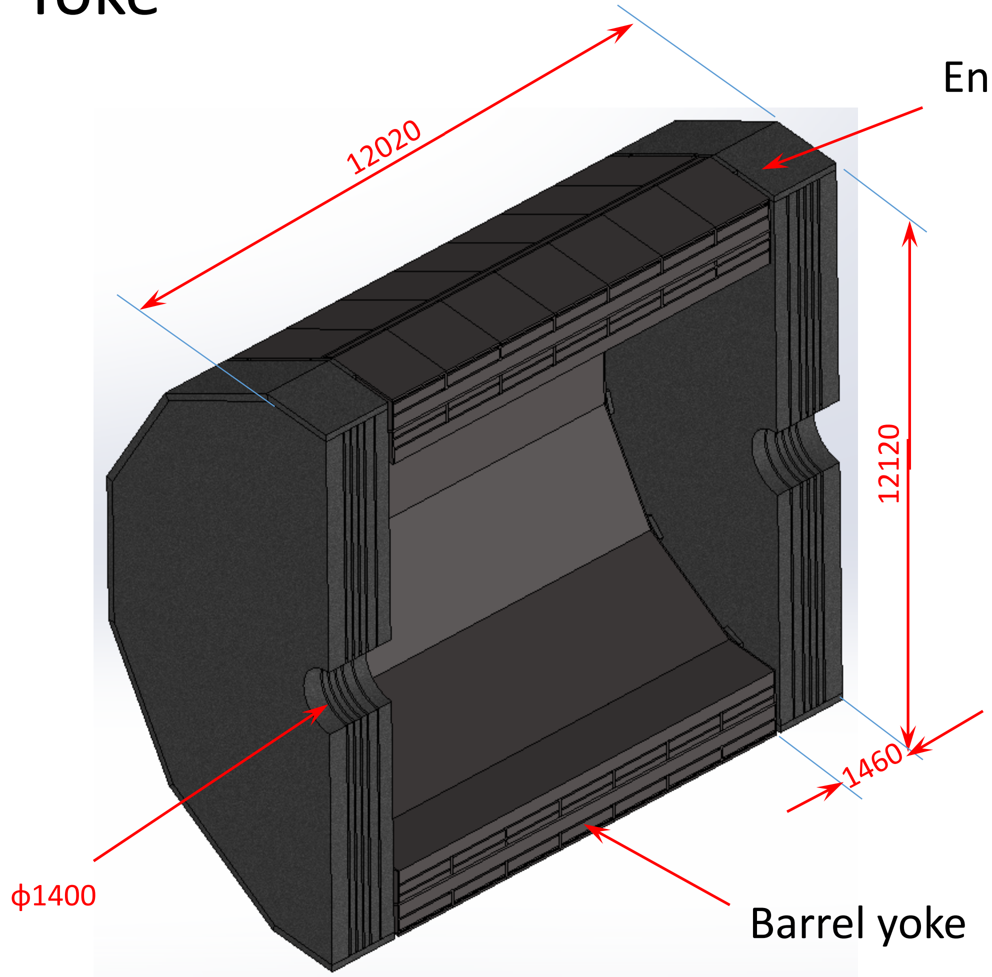
Interface parts:
Yoke
Beampipe



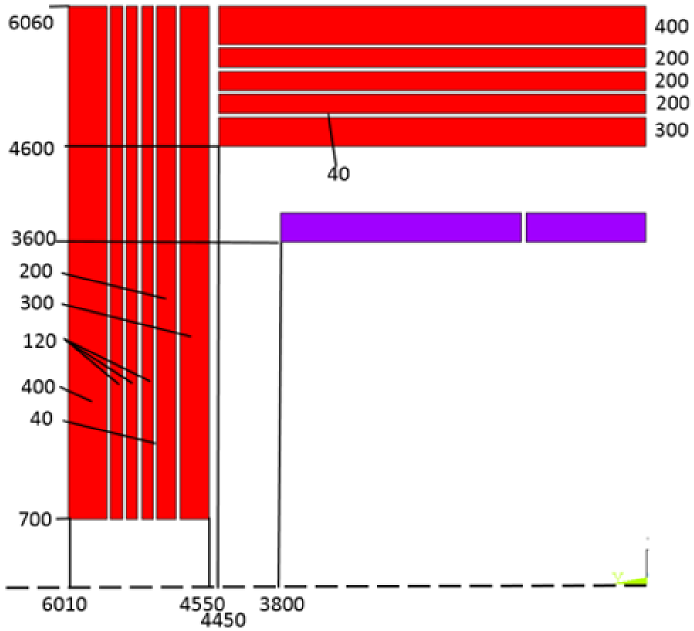


2. Interface requirements and structural design

1) Yoke



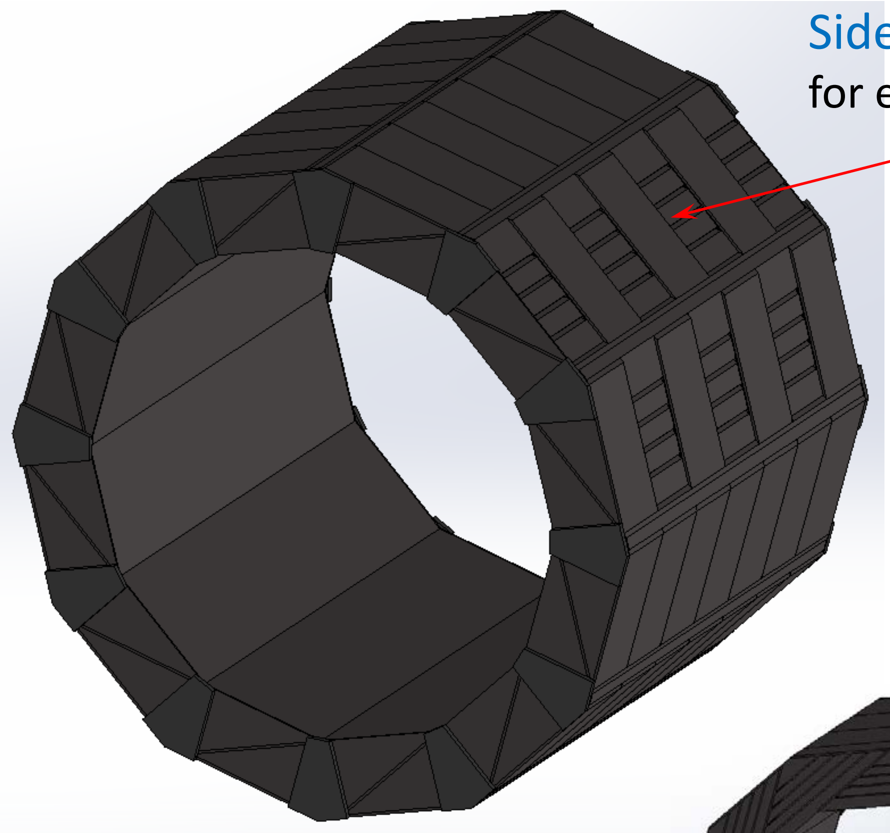
Structural drawing



Yoke iron dimensions
(Zhu zian and Ning feipeng)

Weight:5500 tons

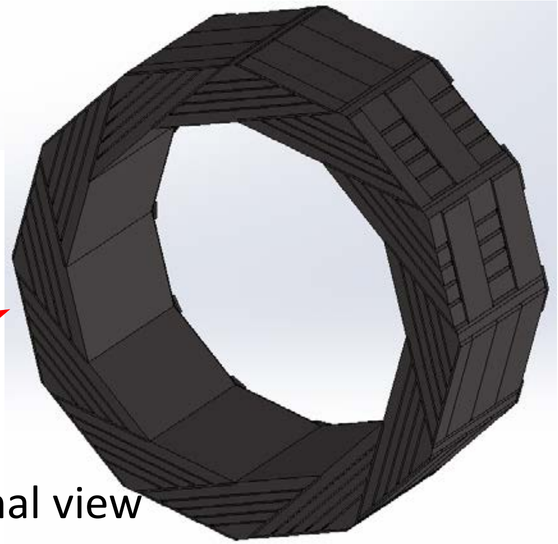
1) Yoke --- barrel yoke



Side open design

for easy maintenance

Weight:3180 tons

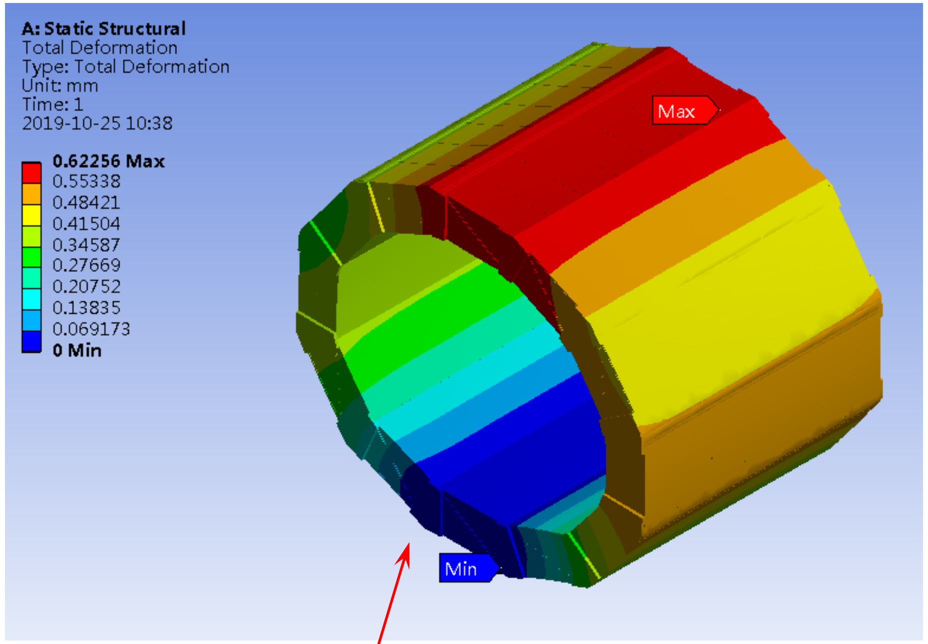


Helical arrangement :

ensures full range detection

Sectional view

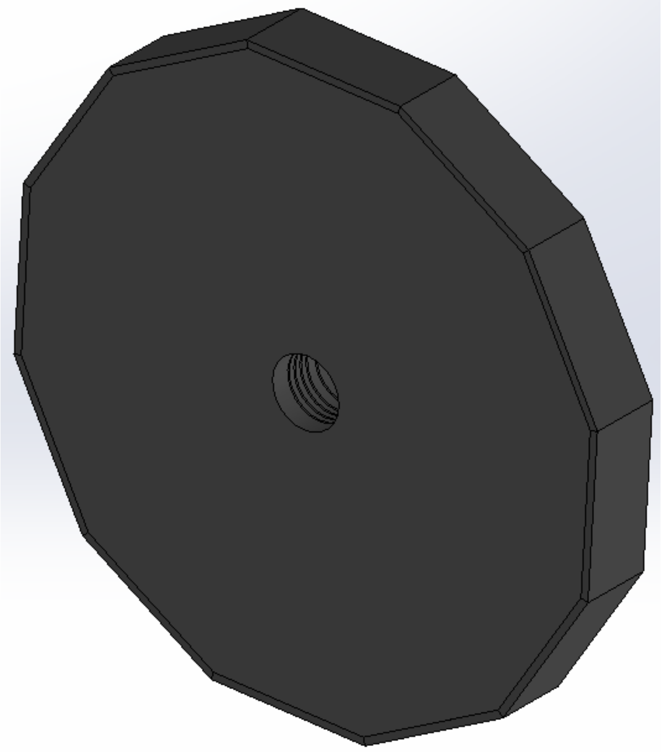
Simulation calculation:

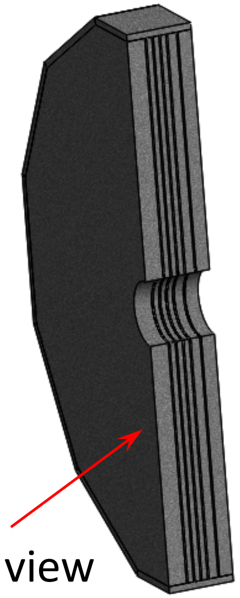


The deformation of its own weight： 0.6mm

Conclusion： Small deformation, safe

1) Yoke --- End yoke

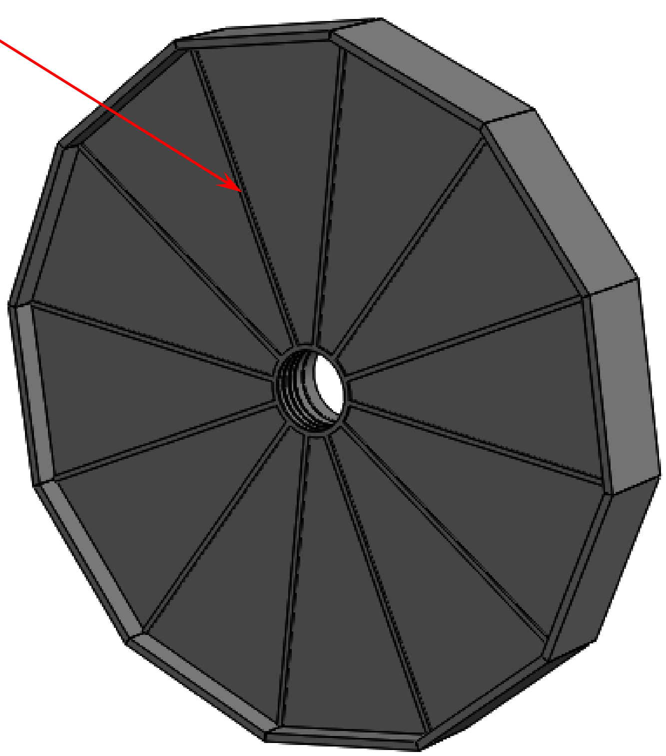




Sectional view

Weight:1165 tons

Strengthening rib



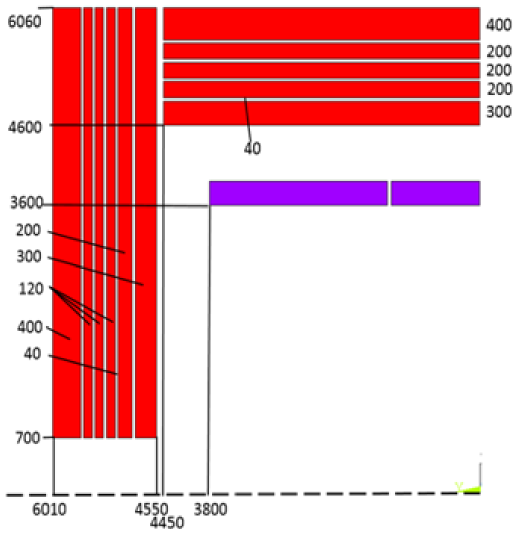
Text:

The strengthen ribs are designed to isolate the end yoke of each layer, ensuring rigidity and reserving space for the Muon detector

Simulation calculation:

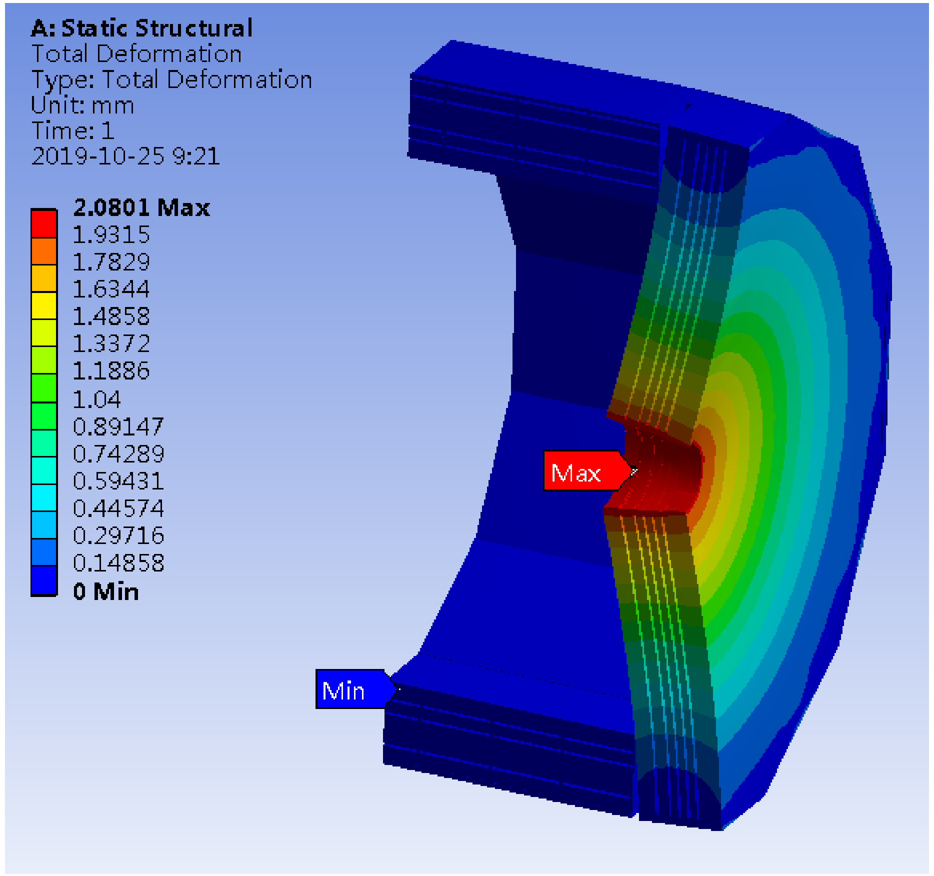
端部受力

端部轭铁从内到外	CEPC new Version（t）
1	3230
2	1702
3	835
4	686
5	546
6	865



The magnetic field force

According to the magnetic field force, calculate the yoke deformation of each layer:



Calculated results:

The first yoke has the greatest deformation, 2.08mm

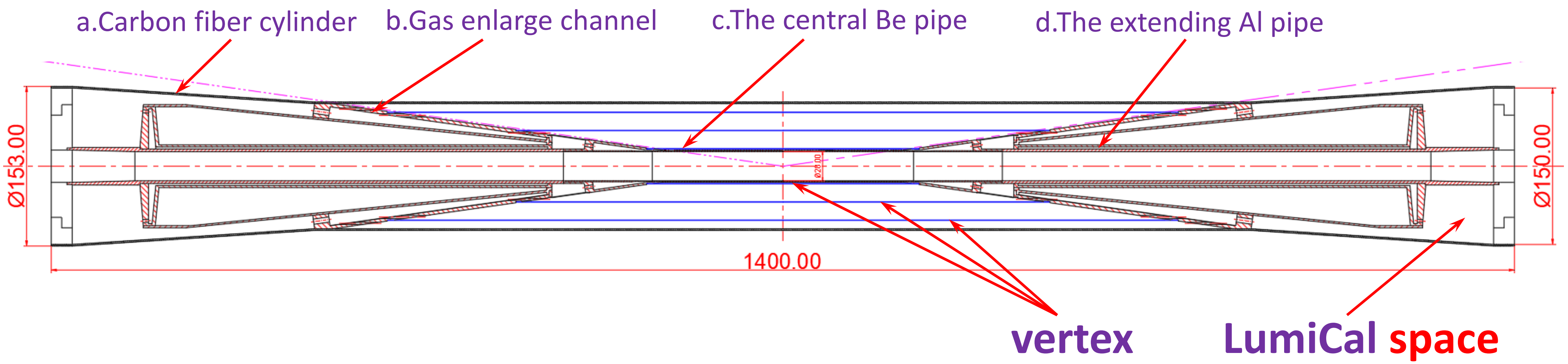
Conclusion： Small deformation, safe

Design parameters of yoke provided according to magnetic field requirements, can meet the strength and stiffness requirements of spectrometer design

2) Beampipe

General design idea：

Optimized space, independent sub-cavity cooling

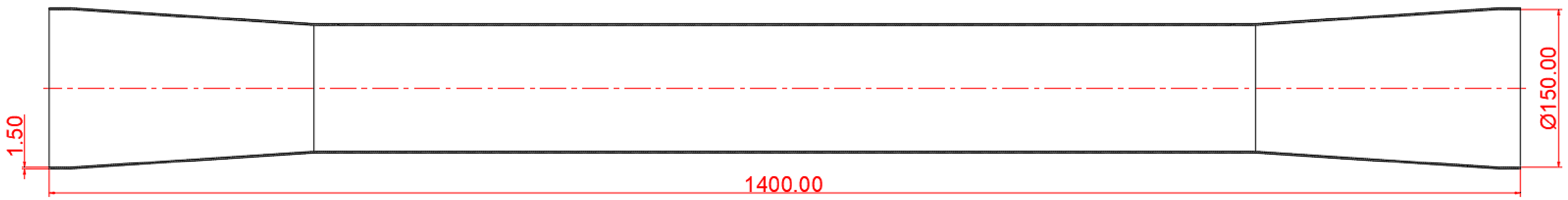


Note:

1.The beam tube consists of four components：a, b, c and d

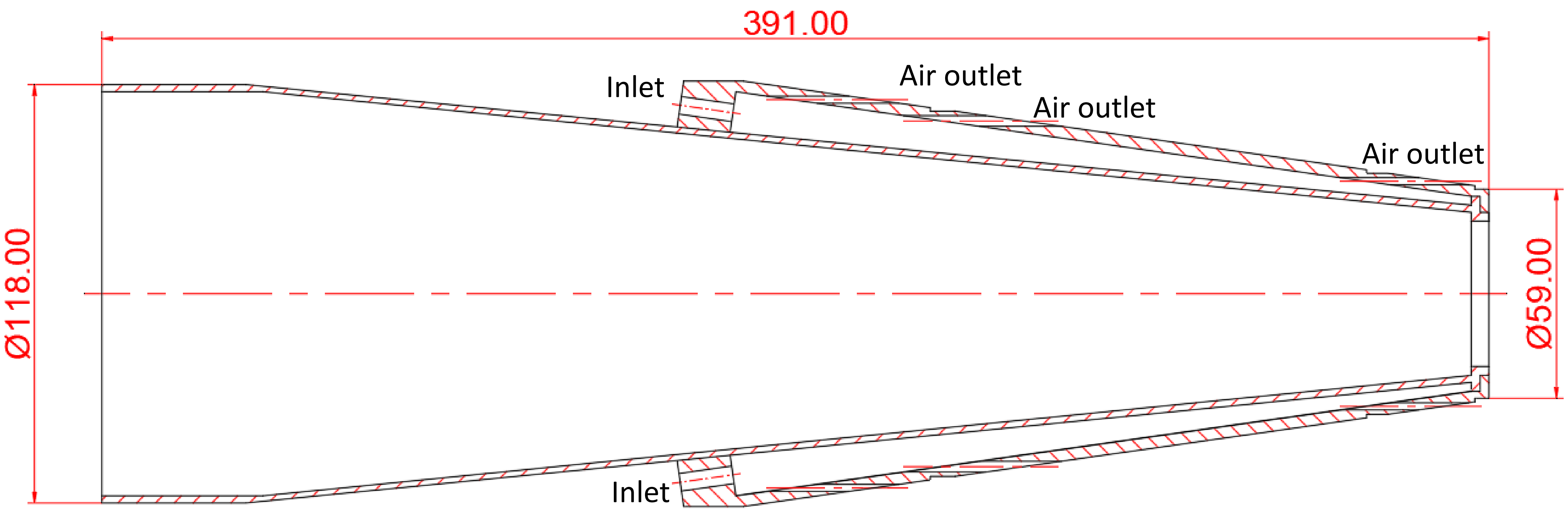
2.On the beampipe, two detectors are installed --- Vertex and Lumical

Component a --- Carbon fiber cylinder (Nov.19,2019)



To strengthen the beampipe, at the same time, Carbon fiber cylinder and Gas enlarge channel form the cooling air duct

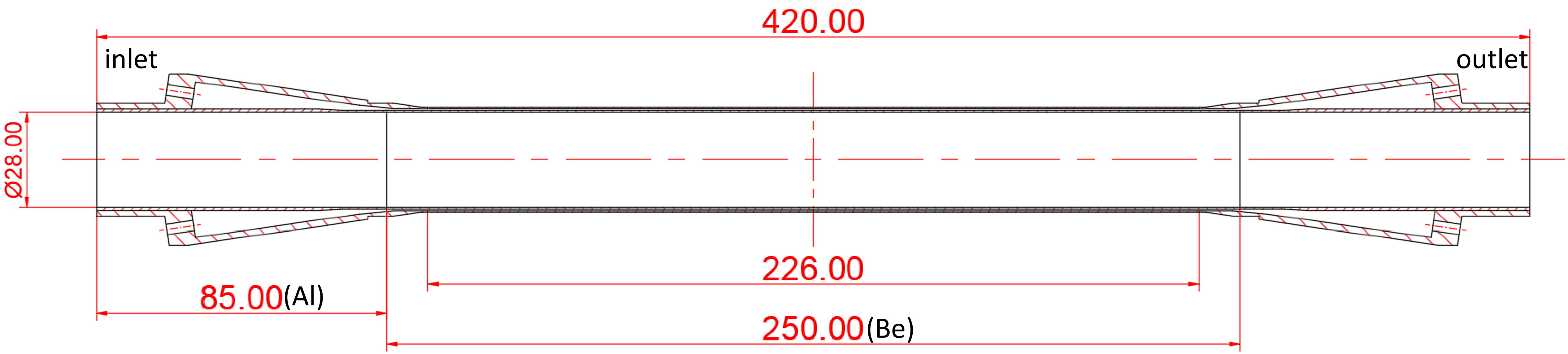
Component b --- Gas enlarge channel (Nov.19,2019)



Coolant: dry air

Three “air outlet”, each cooling different vertex detectors

Component c --- the central Be pipe (Nov.19,2019)



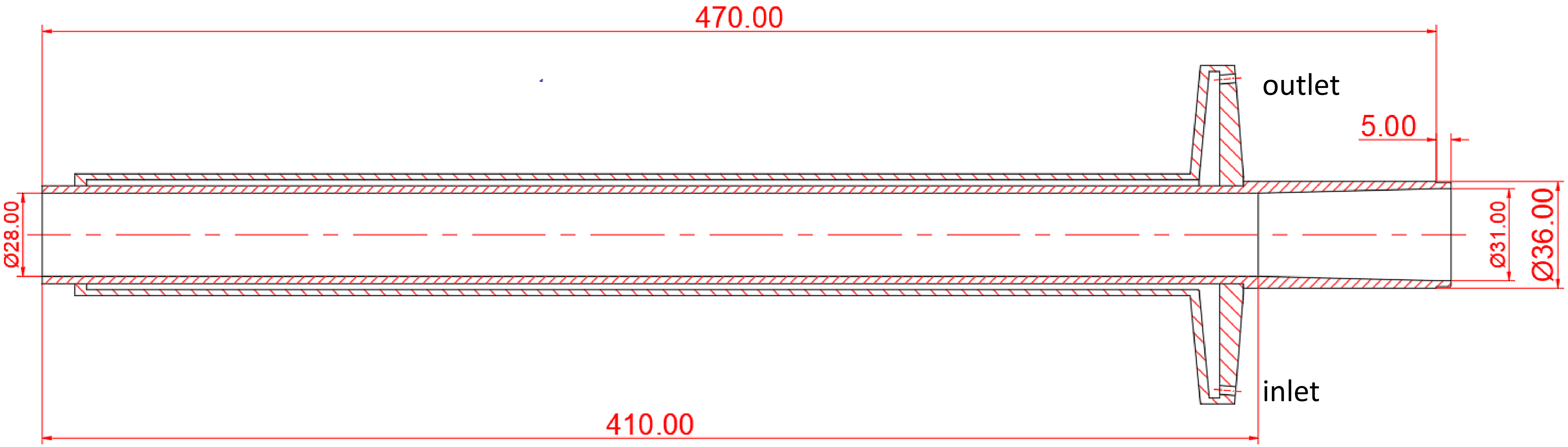
inner Be: T=0.50mm L=420mm D(inner)=Ø28mm

gap: T=0.50mm

outer Be: T=0.35mm L=226mm D(inner)=Ø30mm

Coolant: paraffin

Component d --- the extending Al pipe (Nov.19,2019)



inner pipe: T=2.5mm
gap: T=2.0mm
outer pipe: T=2.0mm

Coolant: water

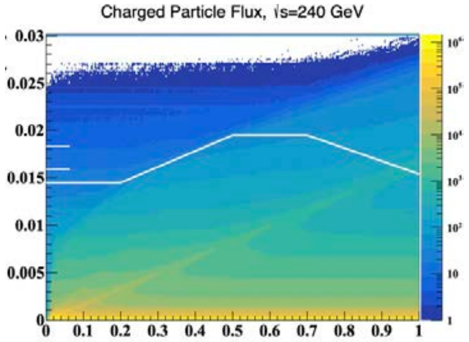
2) Beampipe --- Improved design of inner diameter of vacuum tube

Reason：

Not only the minimum inner diameter of the beam stay clear region but also the detection background must be considered

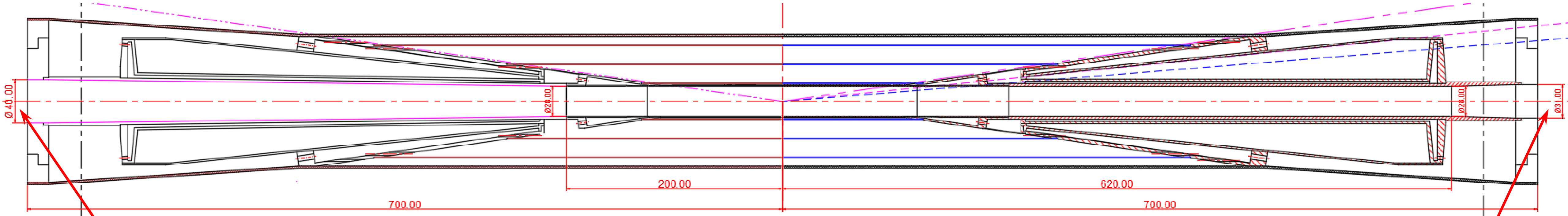
(朱宏博 Zhu hongbo)

After Nov 19， 2019



length(m)	束管最小半径(mm)
0	3.31
0.62	13.89
0.63	14.06
0.64	14.24
0.65	14.41
0.66	14.58
0.67	14.76
0.68	14.93
0.69	15.10
0.7	15.27

(白莎 Bai sha)



ϕ40

ϕ31

Inner diameter under BSC region:

0-620mm ϕ28mm

620-700mm ϕ28 - ϕ31mm

Inner diameter under background :

0-200mm ϕ28mm

200-700mm ϕ40mm

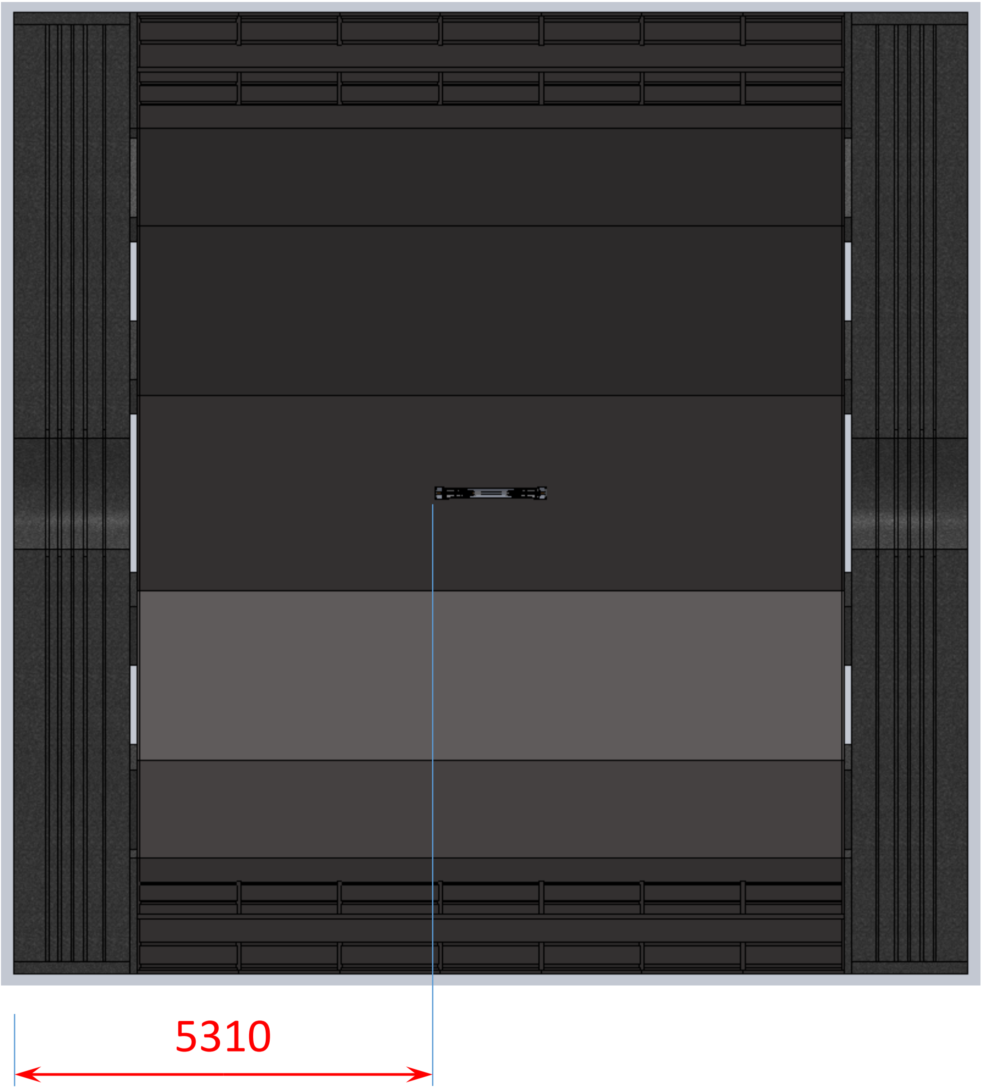
The increase of the vacuum tube slope leads to the increase of heat flux

That means, heat calculation and structural optimization, all over again

2) Beampipe --- Try remote seal design to reduce operating difficulty

Exploration on the design of vacuum seal connection between accelerator vacuum tube and beam pipe

(After Nov 19, 2019, discuss this question with Wang haijing王海静)



As shown in the figure, the installation of beam pipe in the future is very difficult due to its narrow space, and its axial distance from the center is about 5.3 meter.

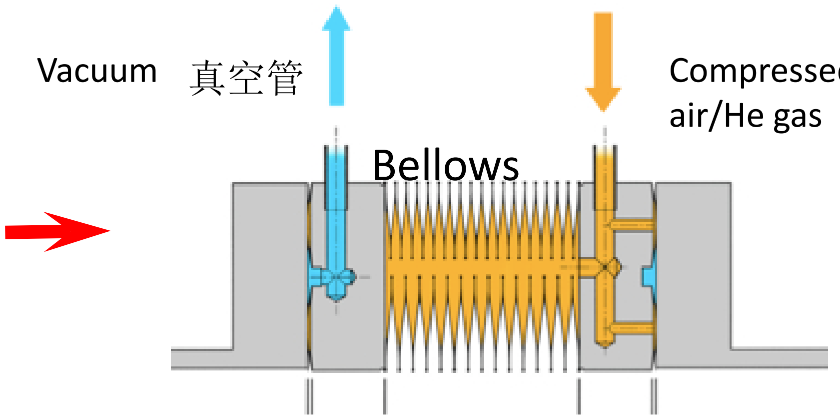
If possible, the use of remote control to achieve sealing, is a good idea

An optional choice: Pillow seal

Pillow seal can be remotely operated by compressed air.

--It consists of two flanges connected by inflatable dual bellows.

--Each flange has a vacuum sealing surface consisting of a thin and Inflatable metal foil, which is polished to a mirror-like one.



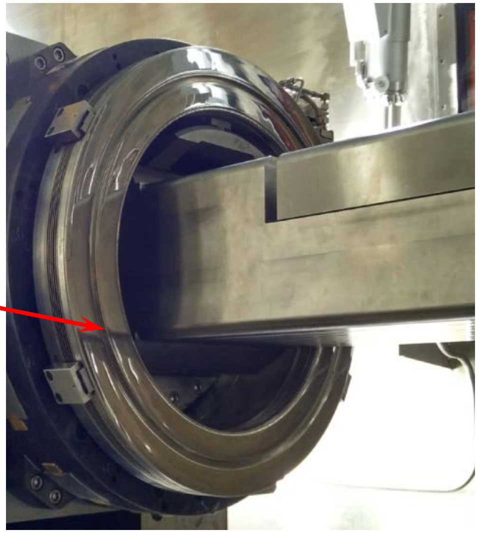
Structure of Pillow seal

Pillow seal has been successfully applied in CSNS.

--in Target system: leak-rate 2.5×10^{-7}Pa.m^3/s.

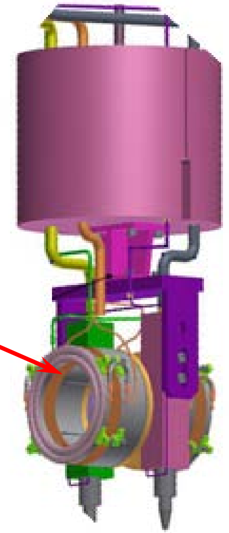
--in Proton Beam Window(PBW): leak-rate 1.0×10^{-9}Pa.m^3/s

Pillow seal



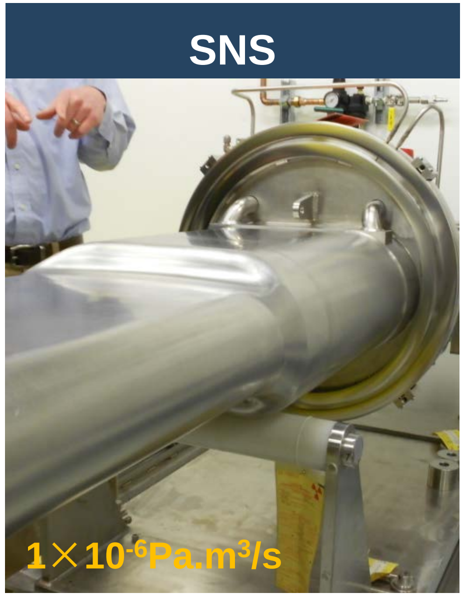
Pillow seal in Target system

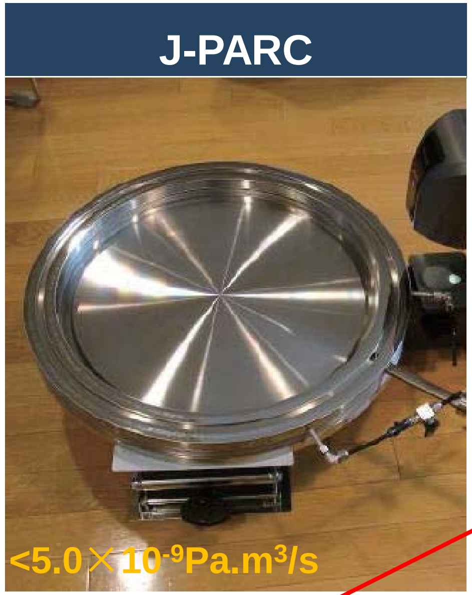
Pillow seal

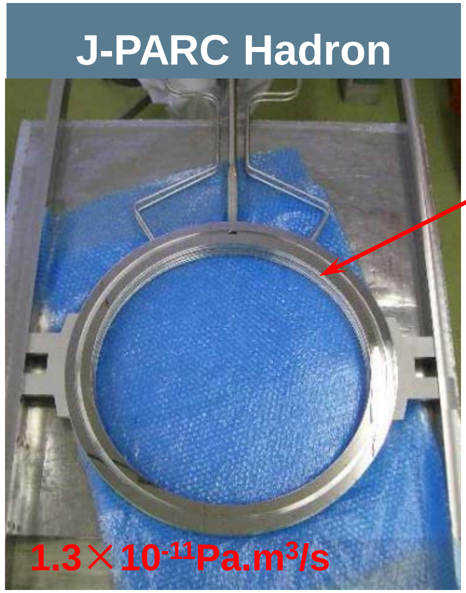


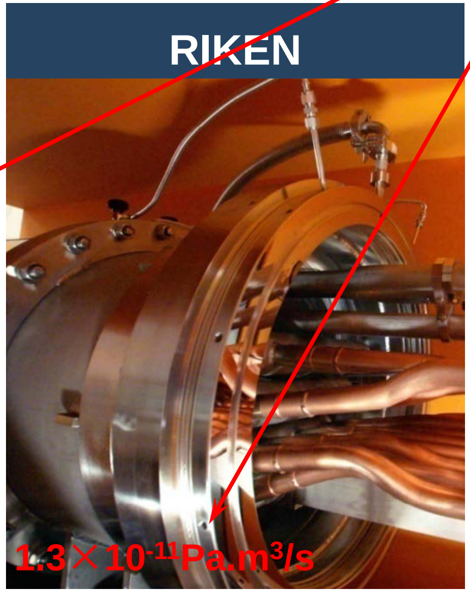
Pillow seal in PBW

Pillow seal in other facilities







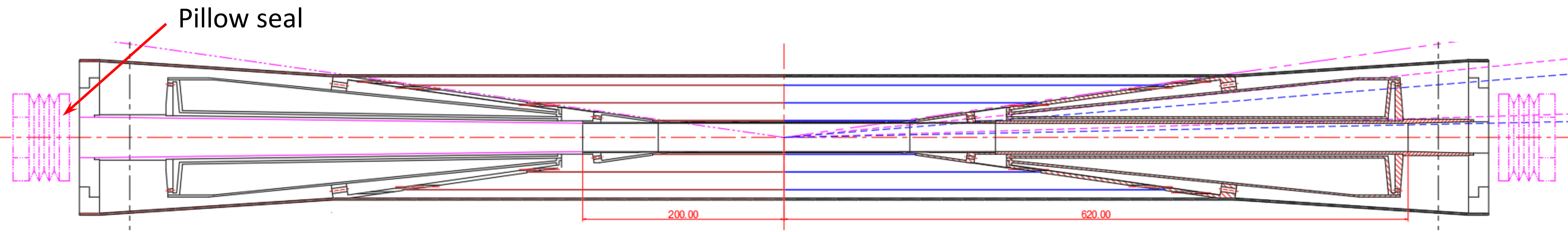


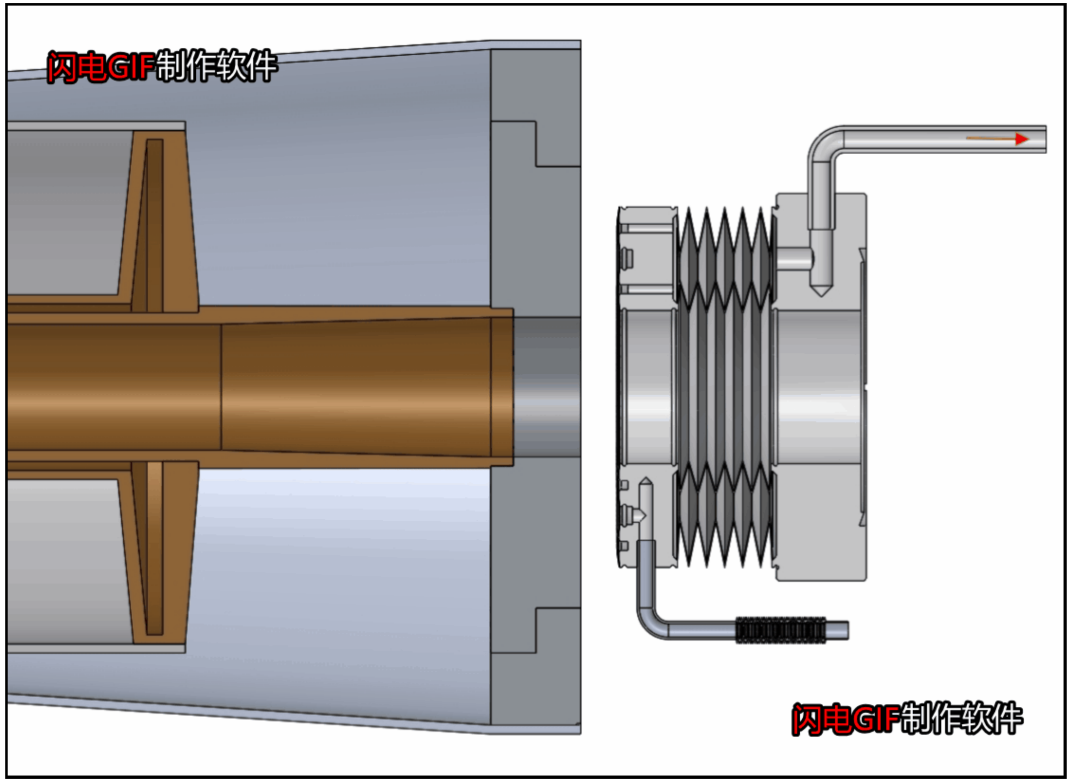
According to the data from Mirapro Co. , Ltd., high sealing performance can be archived.

A leak-rate of **1.3×10^{-11}Pa.m³/s** meets the vacuum design requirements of beam pipe.

So, it is possible to applied Pillow seal to connect accelerator vacuum tube and beam pipe.

Design of vacuum connection structure for pillow seal





The advantages of pillow seal are reflected in the following aspects:

1) Easier and more reliable to operate
2) It saves a lot of space for water, electricity and gas pipelines

Of course, the feasibility of the design needs to be verified by experiments

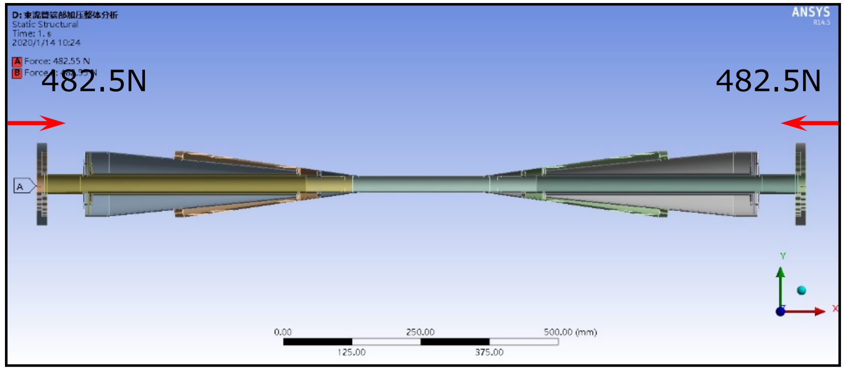
Question:

Can thin-walled beryllium pipe support the inflation pressure of pillow seal?

Simulation calculation 1:

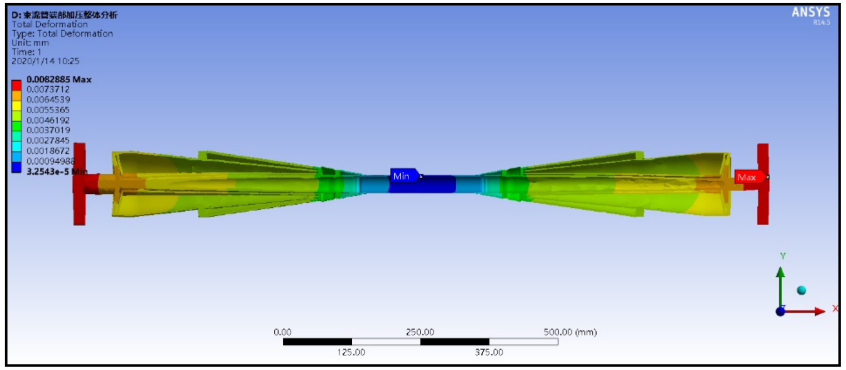
Case1：

Carbon fiber cylinder is not included



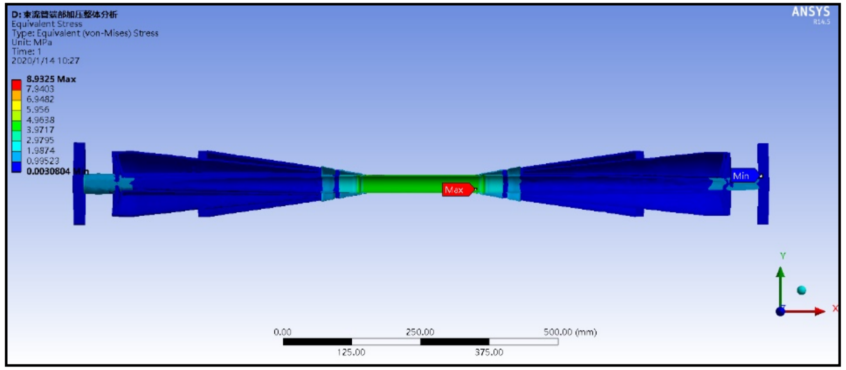
Inflation pressure 0.3MPa

deformation



Maximum deformation of end flange: 0.008mm

stress



Maximum compressive stress of middle beryllium pipe: 8.93MPa

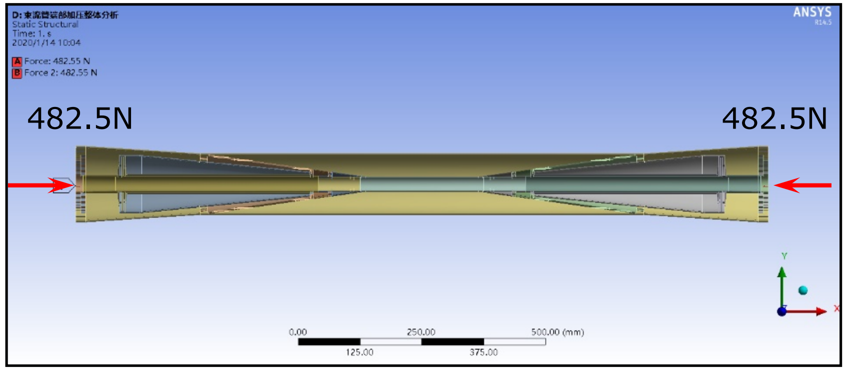
Conclusion：

Meet strength requirements

Simulation calculation 2:

Case2：

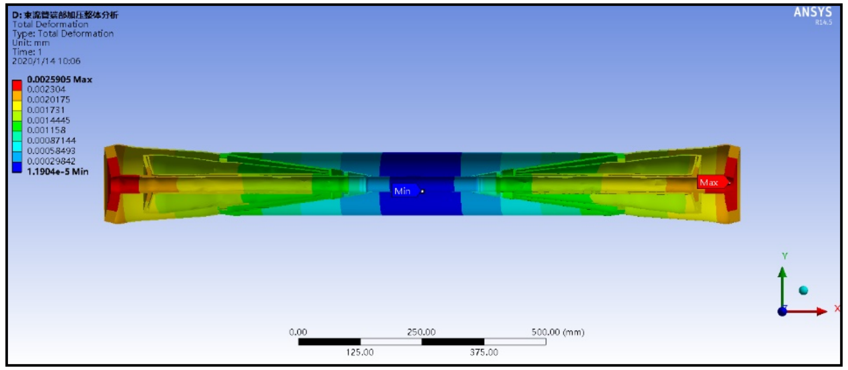
Including carbon fiber cylinder



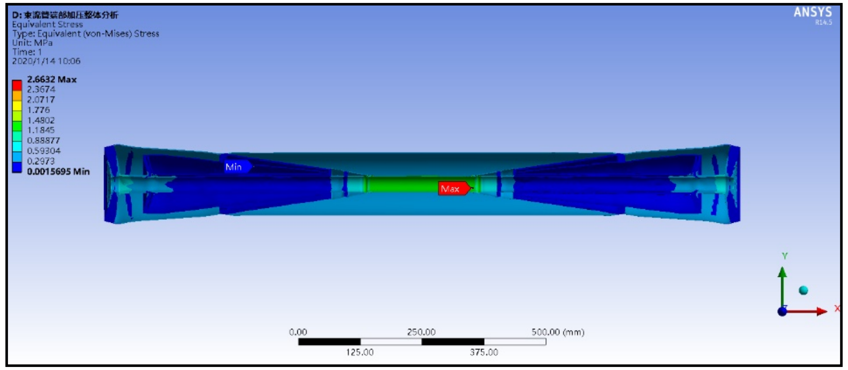
Inflation pressure 0.3MPa

deformation

stress



Maximum deformation of end flange:
0.0026mm



Maximum compressive stress of middle beryllium pipe:
2.66MPa

Conclusion：

Meet strength requirements

In general, the beam pipe is safe under pressure of 0.3mpa at both ends

3. Summary and Next step

1) Summary

- The scheme design of yoke iron and beam pipe in spectrometer is preliminarily completed
- The design boundary between the spectrometer and the accelerator is defined

- Although the background requirements of the detector lead to the improvement of the beam pipe design, it does not affect the overall design idea, but only the optimization of the structural parameters

2) Next step

- According to the design progress of physics and detector, constantly promote the engineering design

- Determine the vacuum connection structure of the accelerator vacuum tube and the beam pipe as soon as possible. (It affects the progress of follow-up work)

Thanks !