CEPC MDI Detector Issues
--- In engineering design

Ji Quan
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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,LumiCal) --- 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
   \[2.66 \times 10^{-11} \text{Pa} \cdot \text{m}^3/\text{s}\]
2. Interface requirements and structural design

1) Yoke

- Yoke iron dimensions (Zhu zian and Ning feipeng)
- Weight: 5500 tons
1) Yoke --- barrel yoke

- Side open design for easy maintenance
- Helical arrangement: ensures full range detection
- Weight: 3180 tons

**Simulation calculation:**

- The deformation of its own weight: 0.6mm

**Conclusion:** Small deformation, safe
1) Yoke --- End yoke

Weight: 1165 tons

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

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)

Three “air outlet”, each cooling different vertex detectors

Coolant: dry air
Component c --- the central Be pipe (Nov.19,2019)

inner Be:  $T=0.50\text{mm}$  $L=420\text{mm}$  $D(\text{inner})=\varnothing 28\text{mm}$

gap:  $T=0.50\text{mm}$

outer Be:  $T=0.35\text{mm}$  $L=226\text{mm}$  $D(\text{inner})=\varnothing 30\text{mm}$

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

Coolant: water

inner pipe: $T=2.5\text{mm}$

gap: $T=2.0\text{mm}$

outer pipe: $T=2.0\text{mm}$
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.

Inner diameter under BSC region:
- 0-620mm: Ø28mm
- 620-700mm: Ø31mm

Inner diameter under background:
- 0-200mm: Ø28mm
- 200-700mm: Ø40mm

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)

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.

**Pillow seal has been successfully applied in CSNS.**
--in **Target system**: leak-rate $2.5 \times 10^{-7}\text{Pa.m}^3/\text{s}$.
--in **Proton Beam Window**(PBW): leak-rate $1.0 \times 10^{-9}\text{Pa.m}^3/\text{s}$
Pillow seal in other facilities

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

A leak-rate of $1.3 \times 10^{-11} \text{Pa.m}^3/\text{s}$ meets the vacuum design requirements of beam pipe.

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

**Case 1:**
Carbon fiber cylinder is not included

- Inflation pressure: 0.3MPa
- Maximum deformation of end flange: 0.008mm
- Maximum compressive stress of middle beryllium pipe: 8.93MPa

**Conclusion:**
Meet strength requirements
Simulation calculation 2:

Case 2:
Including carbon fiber cylinder

Inflation pressure 0.3MPa

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!