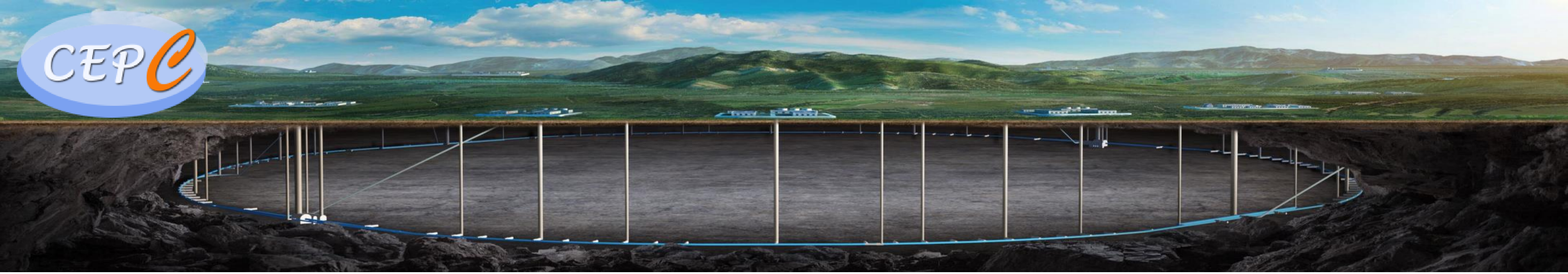

Challenge of CEPC detector installation and integration

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On behalf of the mechanical design group

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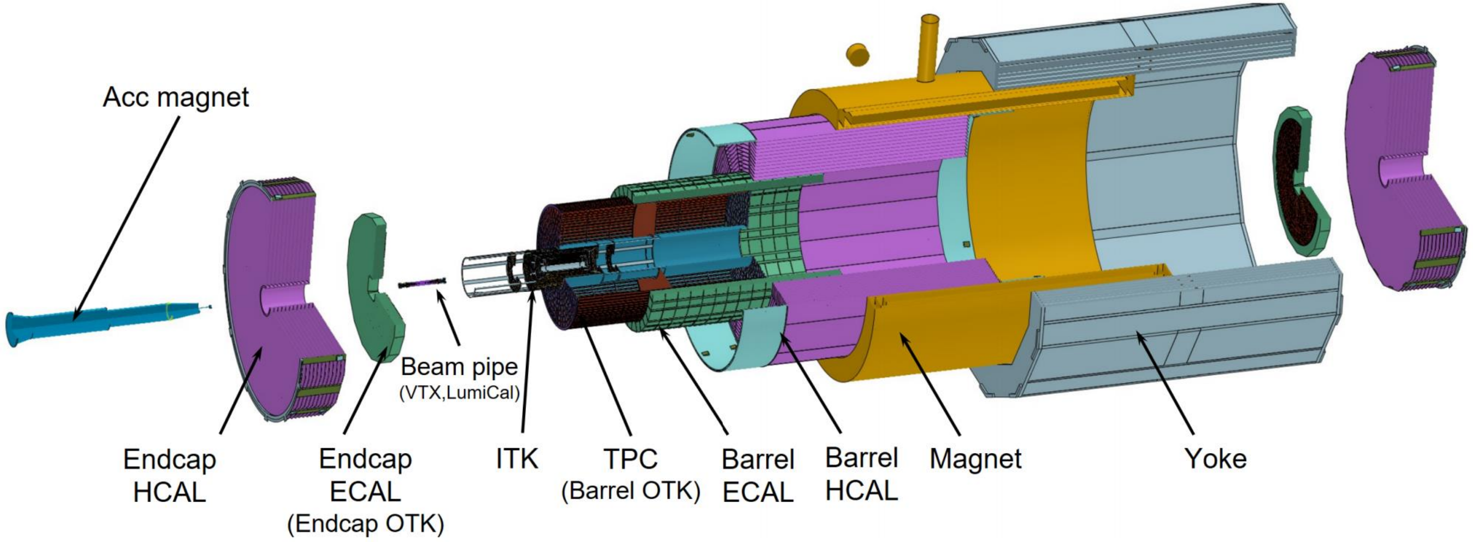
Outline

- ☐ Installation scheme of CEPC detector
- ☐ Installation fixture for sub-detector
- ☐ Movable platform for huge detector
- ☐ Difficulties in survey
- ☐ Service
  - Cable routing
  - Cooling system

Installation scheme of CEPC detector

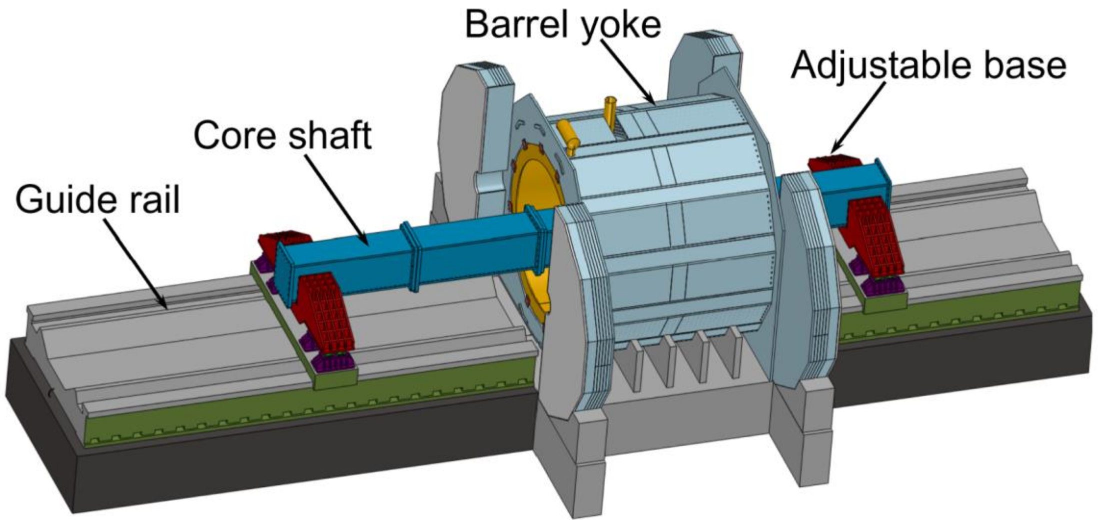
- Installation sequence
  - Start from the yokes (muon detector)
  - Sequence: barrel sub-detectors →endcap sub-detectors
  - Barrel: proceeds from the outside to inside, Magnet→ HCAL → ECAL → TPC (OTK) → ITK → Beam piple assembly (VTX, LumiCal)
  - Endcap: proceeds from the inside to outside, ECAL (OTK) → HCAL → closing yoke



Explode view of sub-detectors installation

Installation scheme of CEPC detector

- Different installation methods were proposed to the various sub-detectors
  - Alternating installation method: Yokes and magnet
  - Core shaft installation method: for heavy-duty sub-detector
  - Cantilever installation method: for light-duty sub-detector



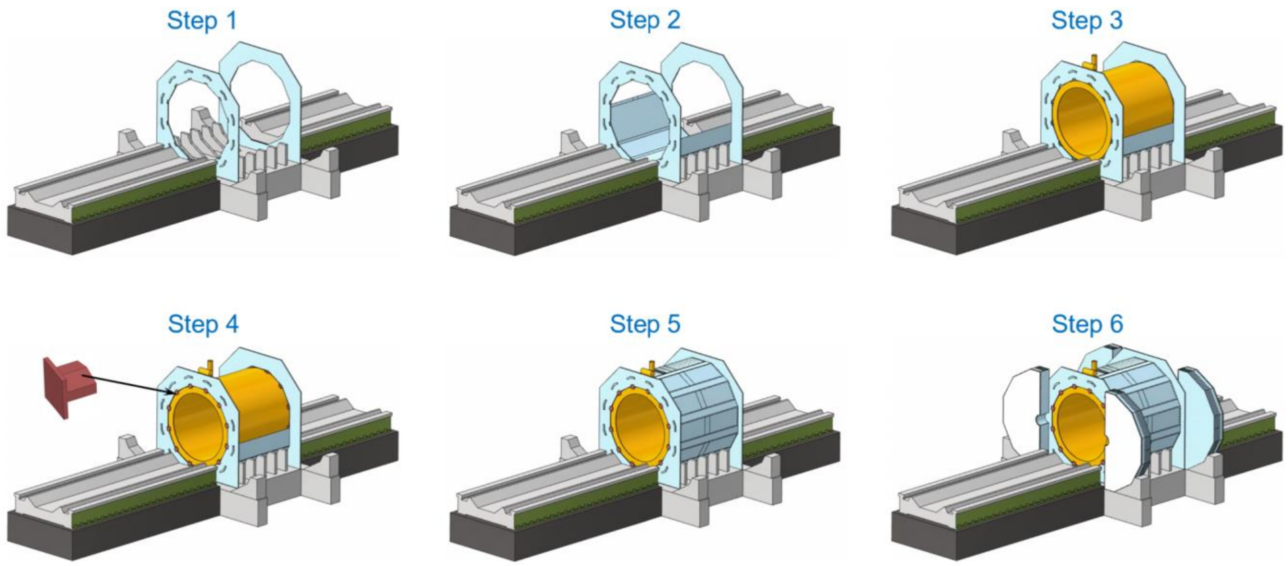
Detector installation in the underground experimental hall

Alternating installation method

- Yokes (muon detector) and magnet

Barrel yoke design ideas:

- Inter-supporting connection structure by mutual support → enables tool-free installation
- Adding end flanges to improve the structural rigidity → deformation is reduced significantly



Alternating installation for yokes and magnet

Core shaft installation method

- For heavy-duty sub-detectors
  - Barrel HCAL, barrel ECAL

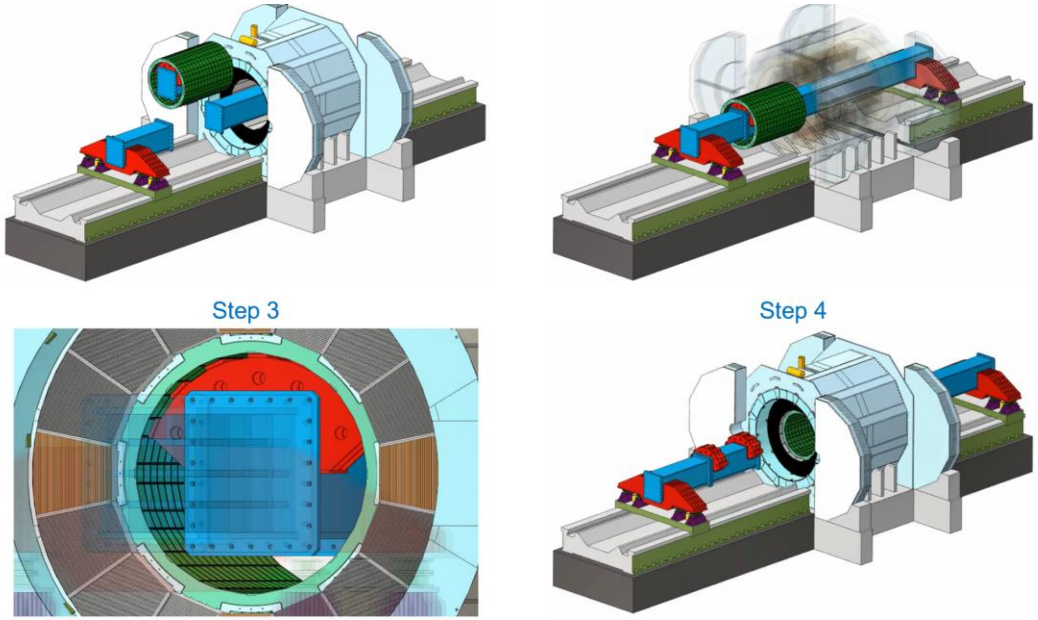
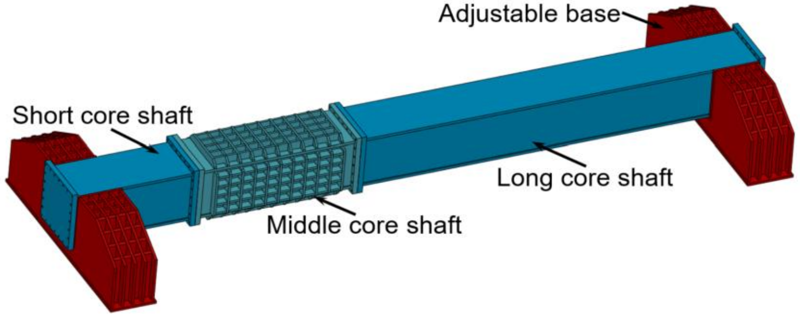
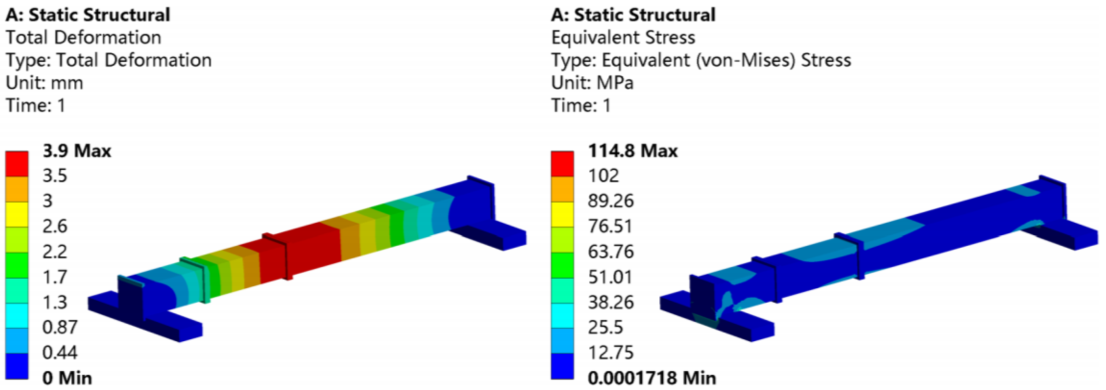


Figure 14.41: Installation process for the barrel ECAL. The barrel ECAL will be assembled with the middle-section shaft and then lifted to connect with other shaft sections.

- Pushed into the barrel yoke along the guide rails
- The segmented design of the core shaft make the installation and removal with the sub-detector easier



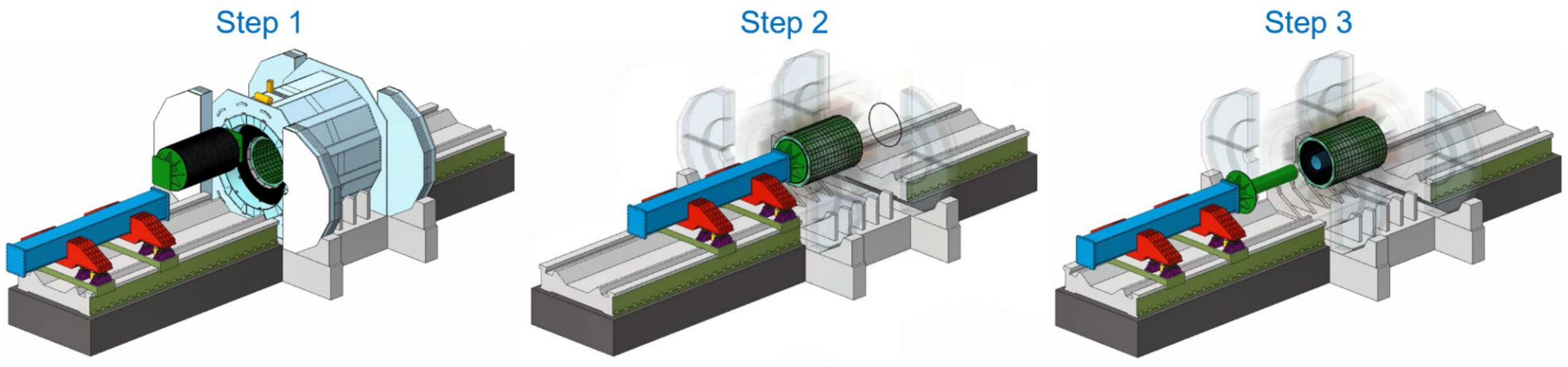
Three-section modular structure of the core shaft.



FEA of the worst case: during installing HCAL, 1000 tons load

Cantilever installation method

- For light-duty sub-detectors
  - TPC (barrel OTK), ITK, endcap ECAL (endcap OTK), endcap HCAL, and beam pipe assembly

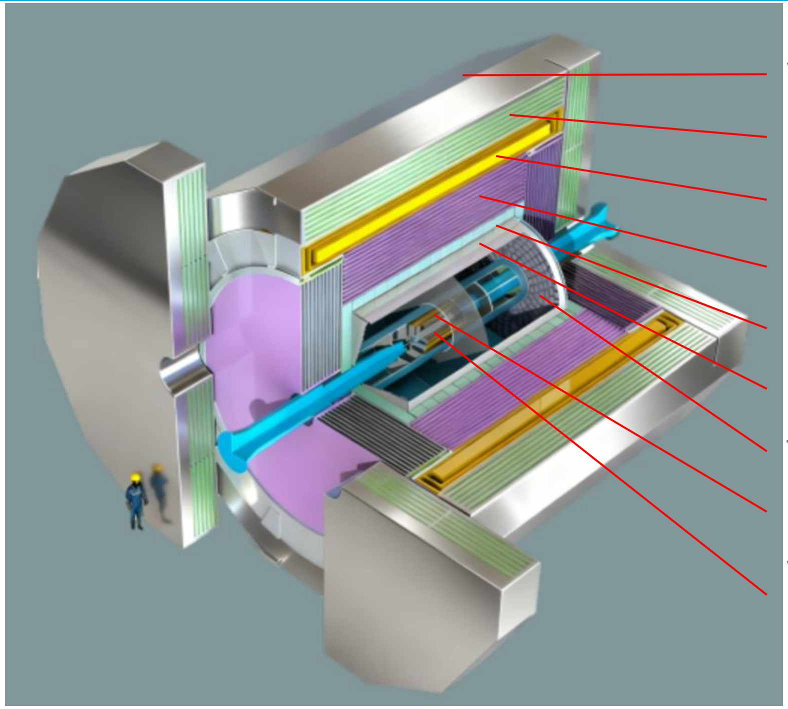


Installation process for the TPC

- One end of the sub-detector fixed to the shaft while the other end kept free
- Considering the deflection at the free end, only suitable to the light-duty sub-detectors

Installation fixture for sub-detector with extreme weight

- 9 sub-detector:
  - Large range of sub-detector weight : 10kg ~3110 tons
- Challenge:
  - **Sub-detector:**
    - Self-structure: Minimize mass & high positioning accuracy (um level)
    - Connect structure→ strength & deformation
  - **Installation fixture**
    - Strong enough→Deformation (sub-detector space 10mm)
    - Adjustable→adjusting accuracy <0.1mm
  - **Optimize the structure of sub-detectors**
  - **Need detail design of installation fixture: control system**

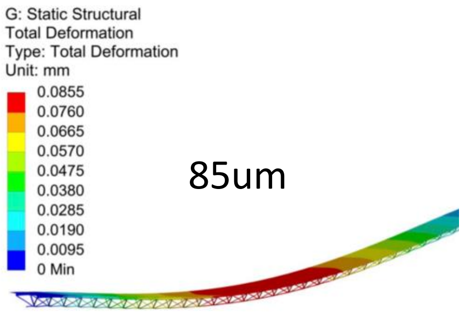


Yoke: 3010 t
Muon: 100 t
Magnet: 250 t
HCAL: 1655 t
ECAL: 180 t
OTK: 400 kg
TPC: 1600 kg
ITK: 80 kg
Vertex+LumiCal+ Beam pipe: 10 kg

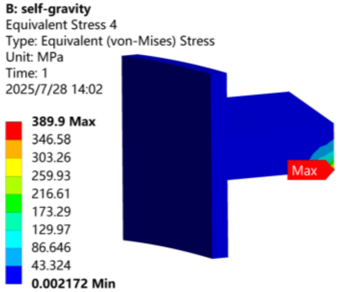
heavy-duty sub-detector

light-duty sub-detector

Sub-detector weight



ITK gravitational sag analysis



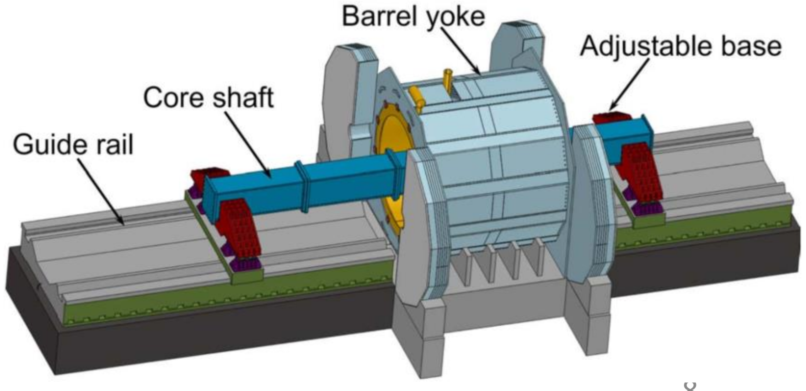
structure in gravity load. The maximum ress is 390 MPa

Connection parts of HCAL: 389.9MPa

Table 14.1: Boundary tolerance, installation clearance and coaxiality of sub-detectors

Detector	Boundary dimensional tolerance (mm) Outer	Boundary dimensional tolerance (mm) Inner	Installation clearance (mm)	Coaxiality (mm)
Yoke	±2			±0.5
Magnet	0 to -5	0 to +5	10	±1
HCAL	0 to -5	0 to +5	10	±0.5
ECAL	0 to -5	0 to +5	10	±0.5
TPC	0 to -2	0 to +2	10	±0.1
ITK	0 to -2	0 to +2	10	±0.1
Beam pipe assembly	0 to -0.3	0 to +0.3	2	±0.1

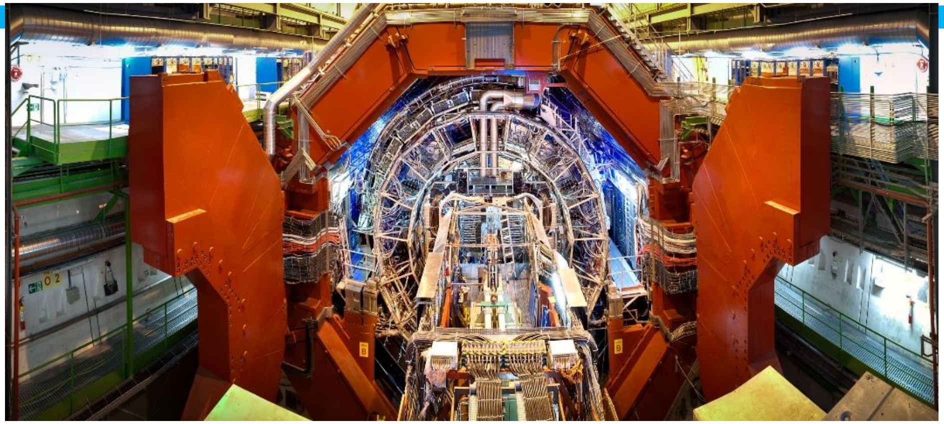
Installation accuracy



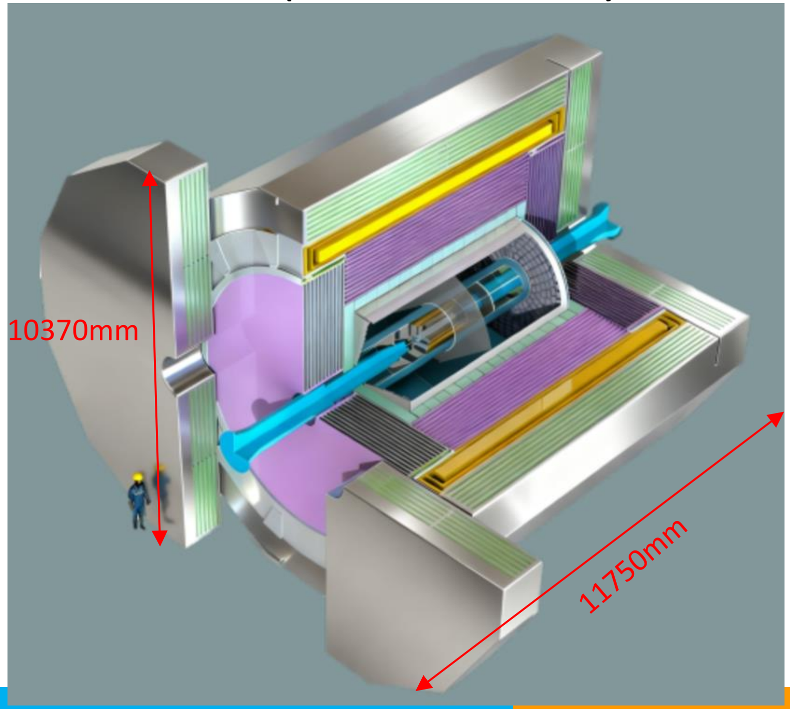
Installation fixture

Movable platform for huge detector

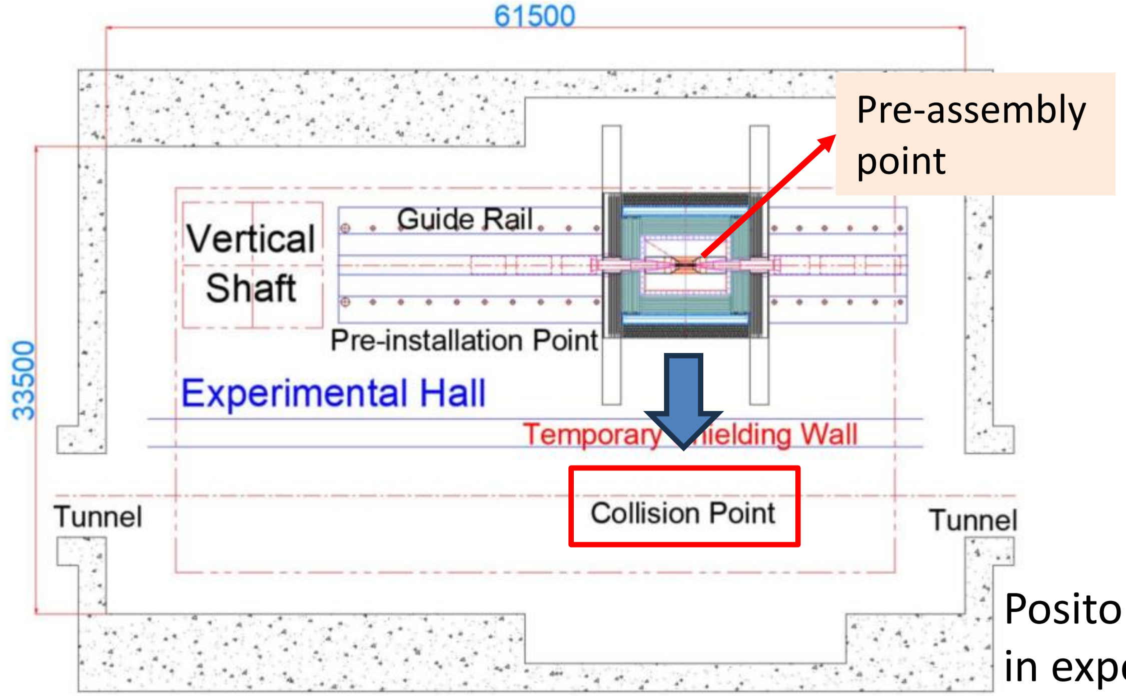
- ☐ Weight of collider detector:
  - ➢ **BESIII**: length: 11m, width: 6.5m, ~800 tons,
  - ➢ **CEPC**: length: 11.75m, width: 10.37m, ~**5205 tons**
  - ➢ **KEKB Belle II**: length: 7.5m, width 7 m, ~1400 tons
  - ➢ **ALICE**: length: 26m, width: 16m, ~10000 tons, no need to move detector
- ☐ Challenge: move the detector as a whole from pre-assembly point to collision point——Detector installation and ACC beam commissioning in parallel
  - ➢ Design a movable platform
  - ➢ Detector position accuracy is less than 1~2 mm



ALICE: 10000 tons



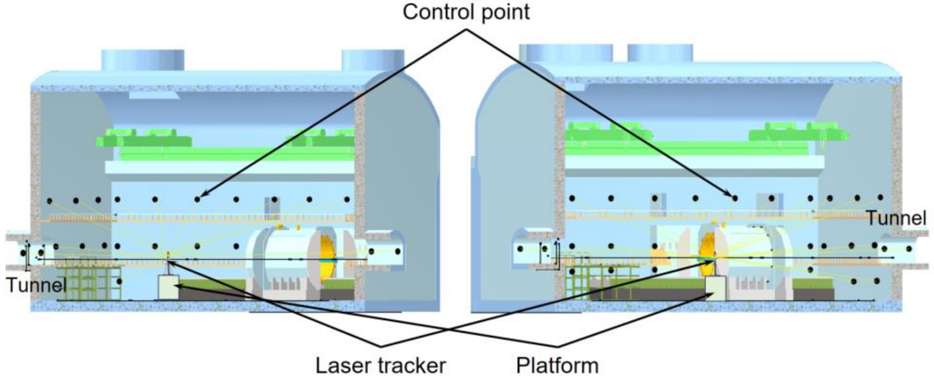
CEPC detector



Positon of detector in experimental hall

Survey of detector

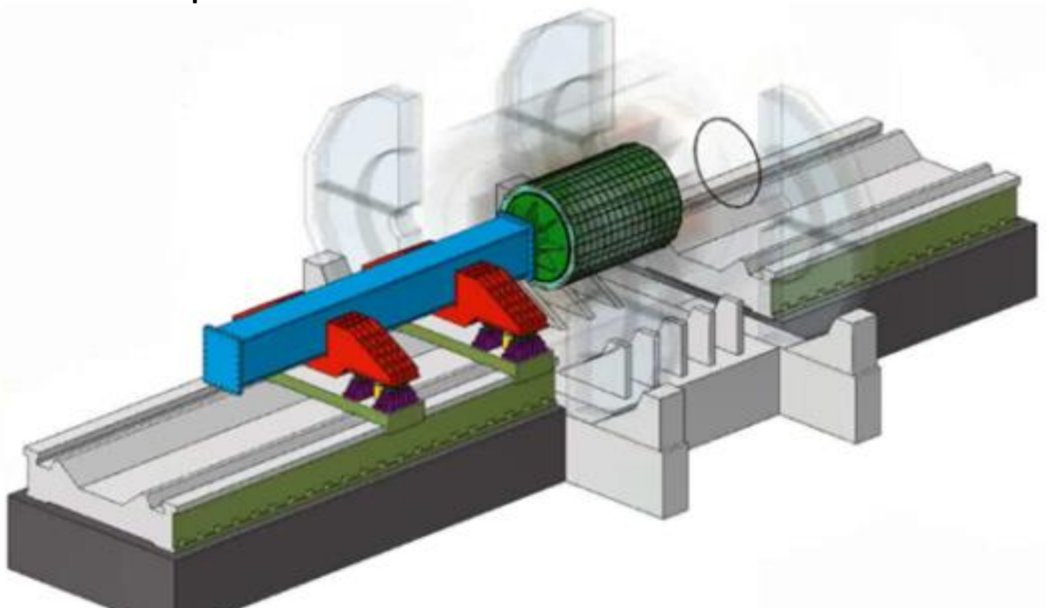
- ☐ Set control points on the walls and floor in experimental hall
  - ➢ Accuracy of high-precision laser tracker: 15 μm + **6 μm/m**——design the control points reasonably to reduce the measurement error (Size of EH: ~62X34X50m)
- ☐ sub-detector positions is critical for VTX and Silicon Tracker to achieve micron-level position resolution
  - ➢ the measurement line of sight would be blocked by installation fixture



Alignment control network in the underground experimental hall

Table: Installation accuracy

Detector	Boundary dimensional tolerance (mm) Outer	Boundary dimensional tolerance (mm) Inner	Installation clearance (mm)	Coaxiality (mm)
Yoke		±2		±0.5
Magnet	0 to -5	0 to +5	10	±1
HCAL	0 to -5	0 to +5	10	±0.5
ECAL	0 to -5	0 to +5	10	±0.5
TPC	0 to -2	0 to +2	10	±0.1
ITK	0 to -2	0 to +2	10	±0.1
Beam pipe assembly	0 to -0.3	0 to +0.3	2	±0.1



Installation of TPC

Service — Cable routing

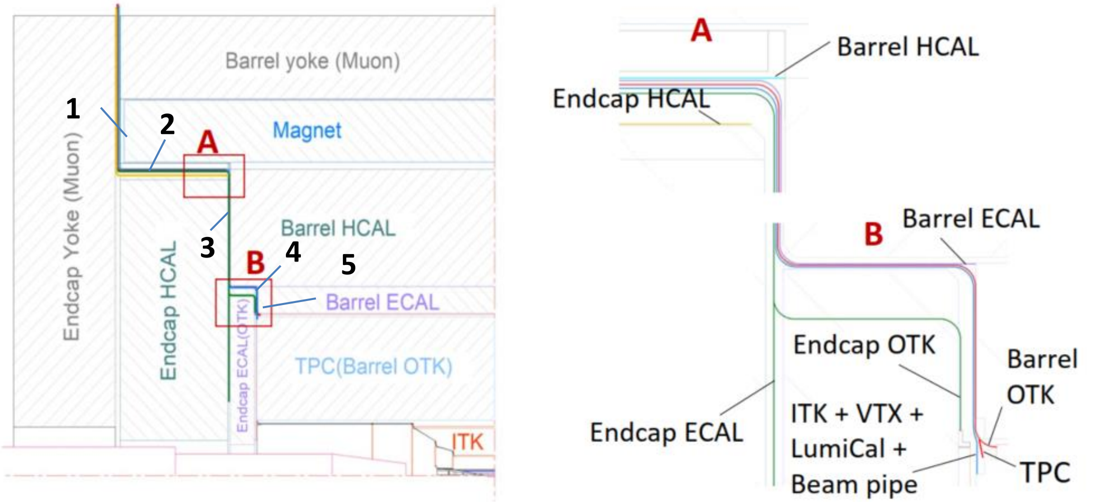
- Num. of cable and cooling pipe for one side: >6000
- Preliminary design the routing in 2D drawing
- Main challenge:
  - Logically sort out the lines of each detector——Especially important for maintenance.
  - Cable fixing frame

Table: Routing gap, cables and pipes, cross section

Channel	Gap (mm)	In channel Cables	In channel Pipes	Cross section (mm^2) Channel	Cross section (mm^2) Cables and Pipes
1	60	5677	581	1.3×10^6	1.4×10^5 (11%)
2	14–80	5677	581	5.1×10^5	1.4×10^5 (27%)
3	30	1336	453	4.0×10^5	4.4×10^4 (11%)
4	30 (Min)	1080	405	3.6×10^5	3.7×10^4 (10%)
5	30	984	357	3.4×10^5	2.9×10^4 (8.5%)

Table 14.4: Inventory of cables and pipes. The quantity in the table represents only one end.

	Cooling pipe Size (mm)	Cooling pipe Number	Cable Size (mm)	Cable Number
Barrel muon detector	/	/	$\phi5$	12
Barrel HCAL	$\phi12$	96	$\phi5$	2784
Barrel ECAL	$\phi10$	80	$\phi5$	240
Barrel OTK	$\phi5.5$	220	$\phi5$	440
TPC	$\phi6$	12	$\phi5$	248
ITK	$\phi5$	69	$\phi5$	101
VTX	$\phi12$	16	$\phi5$	48
LumiCal	/	/	30×6	4
Detector beam pipe	$\phi8$	8	/	/
Endcap OTK	$\phi6$	32	$\phi5$	144
Endcap ECAL	$\phi10$	16	$\phi5$	112
Endcap HCAL	$\phi12$	32	$\phi5$	1536
Endcap muon detector	/	/	$\phi5$	8
Total	/	581	/	5677

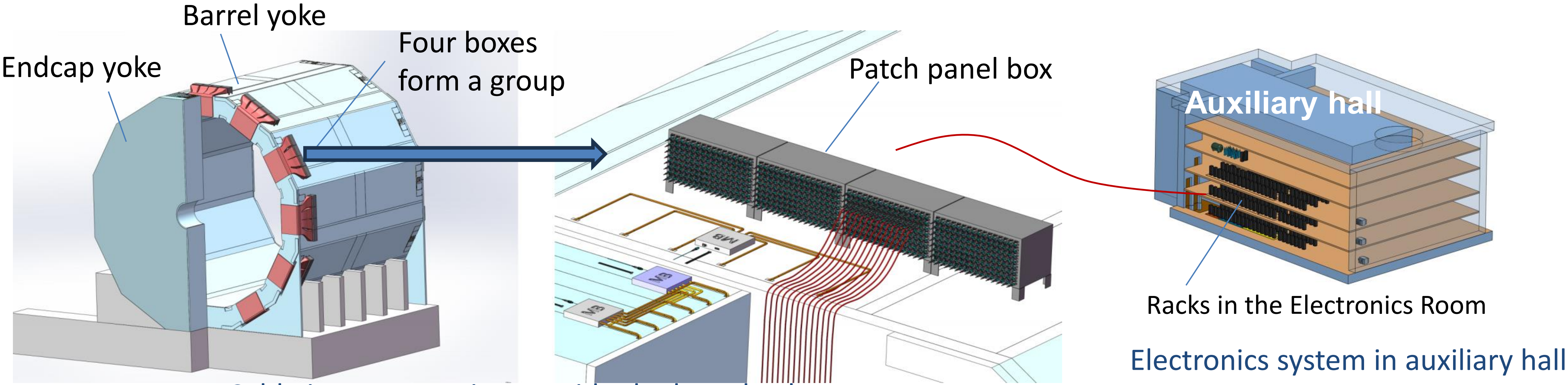


Routing path of sub-detector

Service — Cable routing outside yoke

- How to handle the cables exit from the yoke
  - Grouped and interconnected before go to the electronics room
  - Patch panel boxes are placed on the barrel yoke: allow for future endcap yoke access
  - 11*4=44 boxes: bottom barrel yoke is inconvenient for cable routing
  - Cable count is the same on both sides of the box

Avoid cable being too long and inconvenient to install.



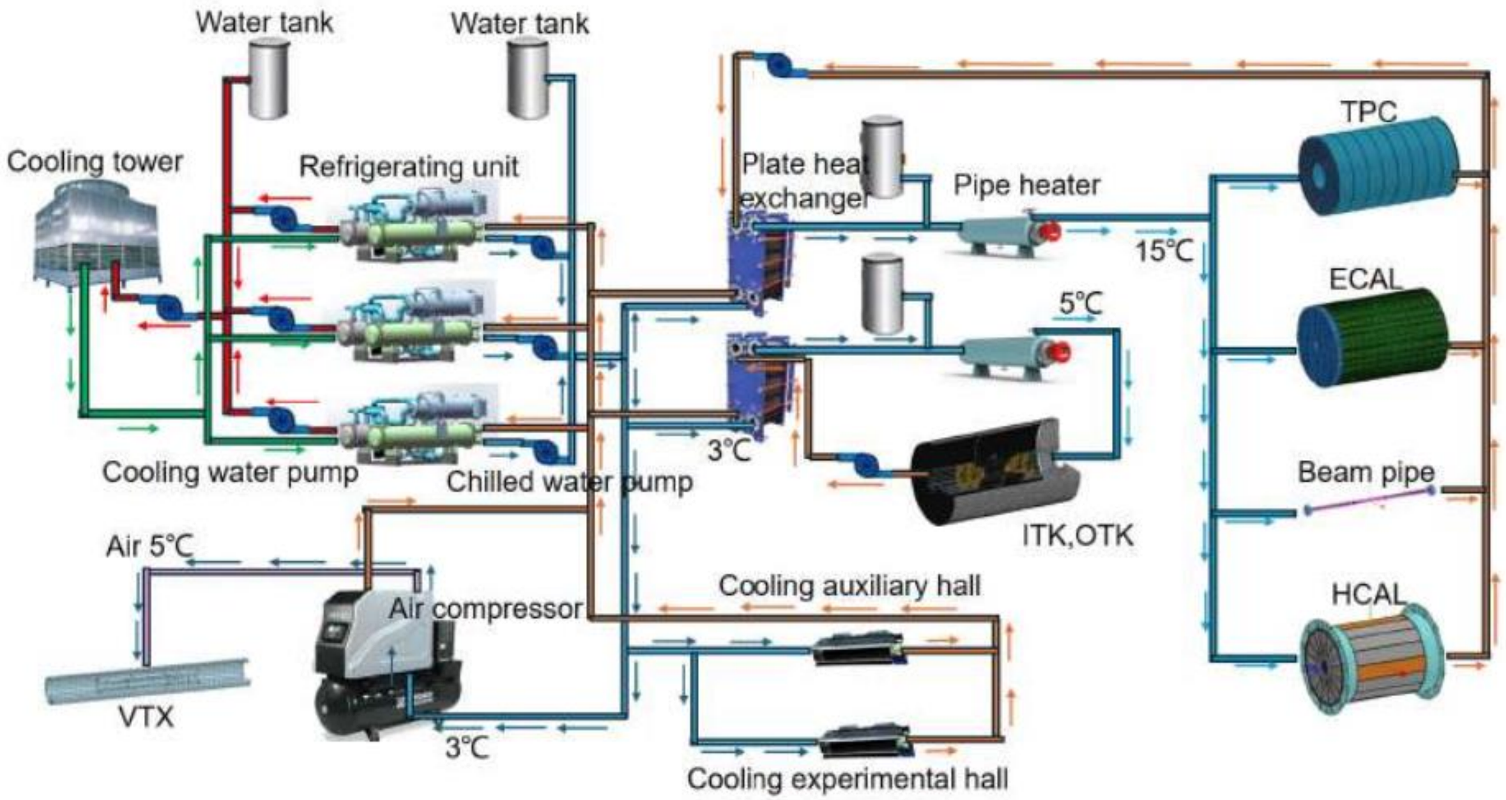
Cable interconnection outside the barrel yoke

Electronics system in auxiliary hall

Cables will undergo interconnection before reaching the electronics room

Service — Cooling system

- Diff. temperature requirement and diff. cooling media: -30~30℃, air/water/CO_2
- Cooling pipe connection in limited space
- Low mass requirement for cooling plate
- Condensed water problem



Flow chart of air conditioning system and cooling system

Summary

- Need to design a high-precision adjustable and high-load installation fixture
- Need a movable platform that can bear more than 5000 t weight to move the detector as a whole from pre-assembly point to collision point
- Experienced survey experts are very important to ensure the installation accuracy of detectors
- Cabling routing needs a patient person who can logically sort out the lots of cables
- The cooling of the detector needs systematic design to get best status of sub-detectors