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CEPC CIVIL ENGINEERING DESIGN*

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Abstract

The CEPC is a circular e+ e- collider located in a 100 km circumference underground tunnel. Preliminary site selection and the design of the CEPC civil engineering will be introduced in this paper.

INTRODUCTION

CEPC consists of a Collider, the injection system into the Collider whose main components are a Linac, a Booster, and transport lines, and two large physics detectors. Civil construction houses all of the components of the CEPC and reserve space for SPPC, as illustrated in Fig. 1. The layout and construction of each part is determined by their geometric relationships, environmental conditions and safety considerations. Practicality, adaptability and operating efficiency are criteria to be carefully considered in the design of the civil construction.

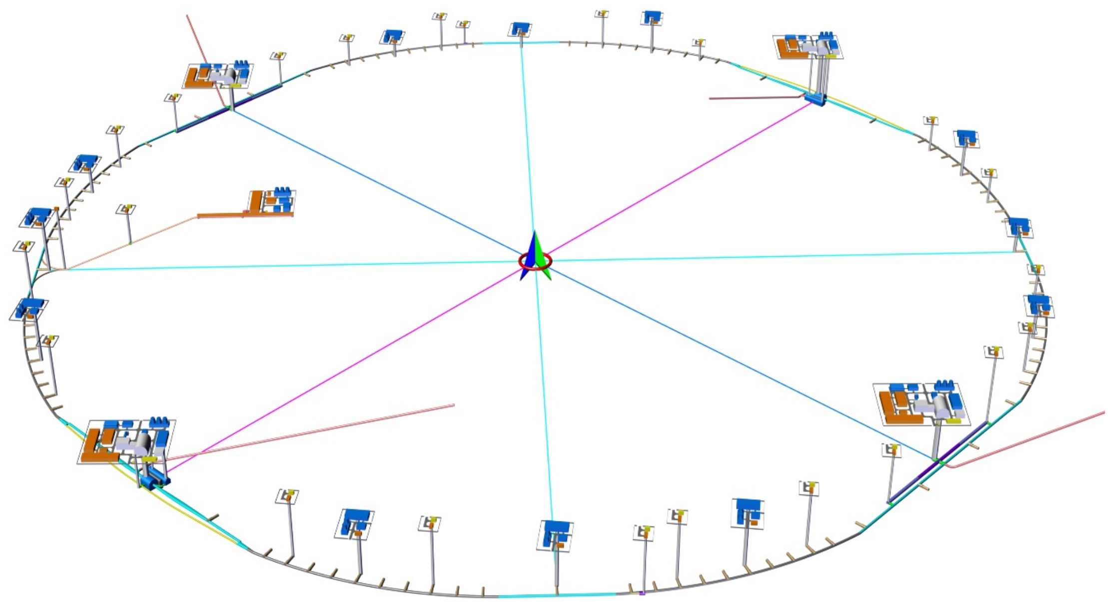

Figure 1: Layout of surface and underground CEPC structures.

The following defines the scope of work and the requirements to be met.

- The main tunnel to house the Collider and Booster synchrotrons, auxiliary tunnels for the Booster bypass and RF equipment, the Linac tunnel and equipment gallery and transport line tunnels. The main tunnel is 100 km in circumference and 100 m below ground.
- The experiment halls are 100 m below ground and span 30~40 m. There are additional chambers such as power source halls, cryogenics halls and spaces for the water cooling system, etc.
- There are accesses to the experiment halls, such as access tunnels, transport shafts, and emergency exits.
- There are ancillary structures at ground level, including structures near the shaft openings, structures to house substations and electric distribution, cryogenics rooms, and ventilation fan rooms.
- Space for staging the construction equipment and materials and dumping sites.
- Included in the project scope are related lifting equipment, conveyance, systems for electric supply, drainage, ventilation and air conditioning, communication, controls and monitoring, safety escape, and firefighting. The firefighting system includes fire alarms, hydrants, gas fire-extinguishing system, and a smoke exhaust system. Maintenance of these systems as well as their potential for future upgrades is fully considered in their design.

PRELIMINARY SITE SELECTION

Basic Principles of Site Selection

In the selection of the CEPC site, besides engineering

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technology conditions such as topography and geology, the construction conditions that need to be considered include location, local government support, social and cultural environment, regional development and environmental impact. These external construction conditions may sometimes be the decisive factor in site selection.

Following are factors that should be considered in the site selection:

- Geography

The site should be sufficiently large and appropriately located to accommodate the future development of the IHEP. The site should promote the CEPC project and the construction of an international science city.

- Natural conditions

1. The structural stability conditions are good and avoid deep faults, motions and deformations that are recent in geologic time. Seismic peak acceleration is generally less than 0.10g.
2. Good rock conditions. Large area hard rock with stable lithology are suitable for construction of underground caverns.
3. No large height differences, mostly low mountains and hilly areas.
4. The quaternary overburden is not thick.
5. The permeability of rock is relatively low.
6. External dynamic geological phenomena are relatively small.

- Access conditions

In order to minimize capital costs and accelerate the progress in the initial stages of the construction, the site should be located where access is convenient.

- Environmental factors

Few environmental impact problems and no environment sensitive zones should be involved, such as nature preserves, parks, military areas, or other environmental constraints.

- Good construction conditions and related economic factors

Brief Introduction of Each Potential Site

A preliminary study of geological conditions for CEPC's potential site location was carried out in Hebei, Guangdong, Shaanxi, Jiangsu, and Zhejiang provinces. The geological survey of site selection in the conceptual design stage was carried out in the Funing site (Hebei Province), in the site of the Shen-Shan Special Cooperation zone (Guangdong Province), and in the site of Huangling area (Shaanxi province).

The Funing site is located in the Funing District, Qinhuangdao City of Hebei Province, Beidaihe District, Changli and Lulong Counties. This is a hilly area, with elevations of 0 m to 600 m. The main strata are Archaean gneiss, Mesozoic magmatic rocks, volcanism from the Yanshan period, and some Mesozoic sand shale. The rock is mainly hard without thick overburden, and has a basic seismic intensity of degree VII. The site conditions are suitable for construction of large underground caverns and tunnels. The depths of the underground caverns do not vary a great deal.

The Shen-Shan site is located in the Shen-Shan Special Cooperation zone, Haifeng and Huidong Counties of Guangdong Province. The landform is dominated by low mountain areas with elevations of 20 m to 800 m. The main strata consist of Mesozoic volcano rock and sand-mudstone, granite of the Yanshan period, and a small amount of Cenozoic shaly glutenite. These rocks are mainly hard with fracture structure, no thick overburden, and the basic seismic intensity degree VI~VII. Some of the caverns will be quite deep and require a long shaft. The layout is relatively complex and difficult to construct.

The Huangling area site is located in Huangling County and Luochuan County (Yan'an City, Shanxi Province), Yijun County (Tongchuan City), and Baishui County (Weinan City). The landform belongs to a plateau gully region with elevations of 600 m to 1600 m. The stratum on the horizontal layer and its lithology is Mesozoic Triassic terrestrial clastic rock, with 100 m to 150 m of overlying loess. The rocks are generally of moderate hardness with simple structure, and the basic seismic intensity is mainly of degree VI. The buried depth of underground caverns and the shaft depths vary considerably. The layout for construction is relatively easy, and the construction work of moderate difficulty.

In the conceptual design, Funing was selected as representative site.

PROJECT LAYOUT AND MAIN STRUCTURE

General Layout Principles and Requirements

- The layout, length and buried depth of the tunnel meet the needs of the accelerator and the detectors.
- The operation needs to be secure, with easy management and convenient traffic flow.
- The geologic structure around the circumference of the tunnel is simple and the hydrogeological conditions are suitable for construction.
- Good water and electricity supply conditions.
- Shafts and adits provide entrance to the tunnel. Shafts will avoid densely populated areas. Auxiliary facilities, such as cooling towers and substations are close to the access shafts.
- The layout must meet the requirements for transportation and installation of experimental equipment.
- The number and length of construction adits should be determined by the terrain and geologic conditions, the construction methods and the external transportation situation. It will help to balance and optimize the required person-hours and time requirements among tunnel sections.
- Minimize the impact on the local ecology. The surface facilities should avoid existing buildings.

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- Meet the requirements of government regulations and norms.

Layout of the Underground Structures

Figure 2 and 3 show the 100 km circumference tunnel in plan and profile. The tunnel has an inverted U-shape, of 6.00 m width 5.00 m height. Considering the relatively thick overburden of the Yanghe River alluvial plain in the southeast part of the site, point B, through which the tunnel passes the Yinma River, is designated as the lowest tunnel point, and point A, opposite to point B along the diameter, is designated as the highest tunnel point. The longitudinal slope of the tunnel is 0.3% from topology as well as drainage requirements during construction and operation. Surrounding rocks of the tunnel consist of granite, gneiss, schist and tuff and are mainly of Class II ~ III.

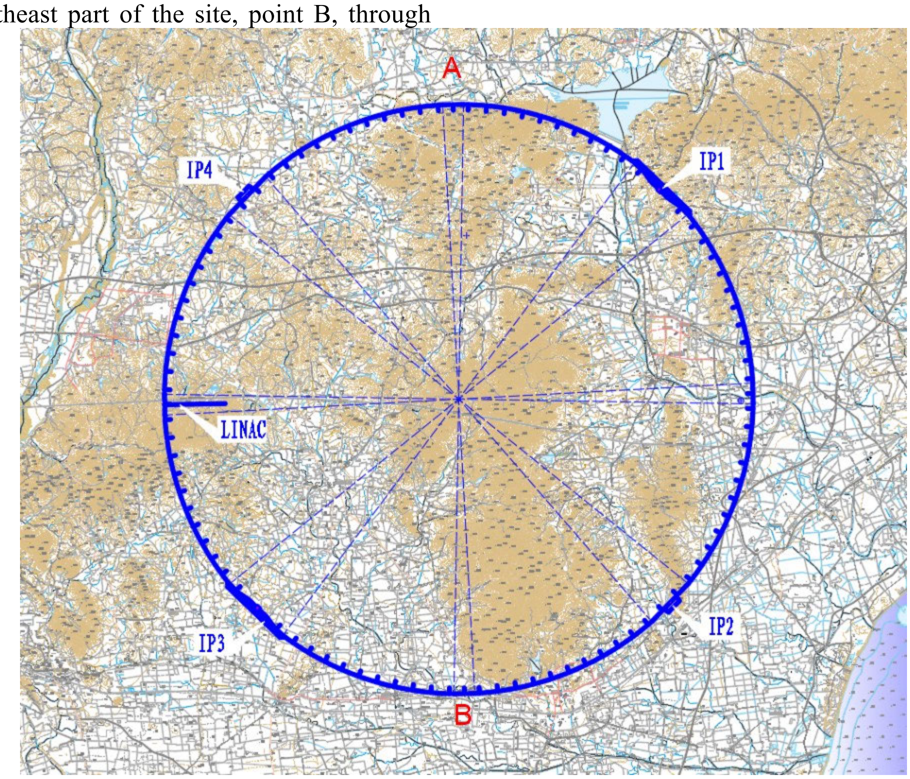

Figure 2: Layout Plan of the CEPC Tunnel.

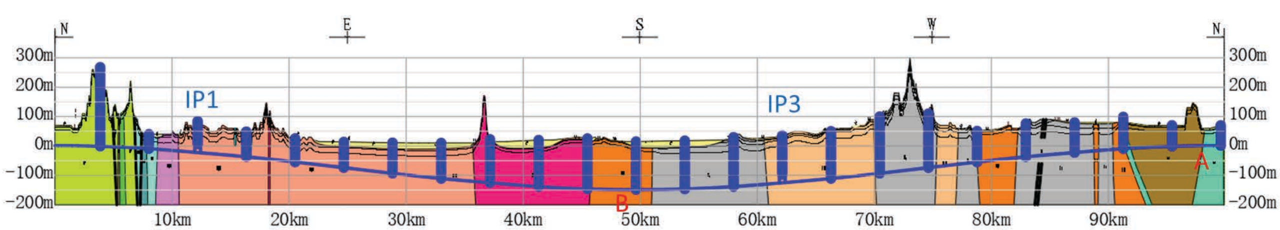

Figure 3: Longitudinal Profile of the CEPC Tunnel.

Underground structures consist of the following as shown in Fig. 4:

- Collider ring tunnel (L=99.67 km);
- Experiment halls (includes main and service caverns): IP1 and IP3 are experiment halls for CEPC, and IP2 and IP4 are future experiment halls for SPPC;
- Linac and BTL tunnels: Linac tunnel, klystron gallery, hall for the damping ring, BTL tunnel and its branch tunnels;
- Auxiliary tunnels: RF auxiliary tunnels, Booster bypass tunnels in the IR and many short auxiliary tunnels;
- Vertical shafts in experiment halls and RF zones and along the ring tunnel for personnel and delivery of equipment to tunnels and halls, and for providing channels for ventilation, refrigeration, cooling and control and monitoring lines.

Layout of the Surface Structures

All surface structures shall be as close to the access shafts as possible. In these buildings are located water cooling facilities, low-temperature facilities, ventilation systems, air compression systems, power transformer substations and electrical transmission and distribution

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and DC power supplies. The total area of surface structures is 140450m^2.

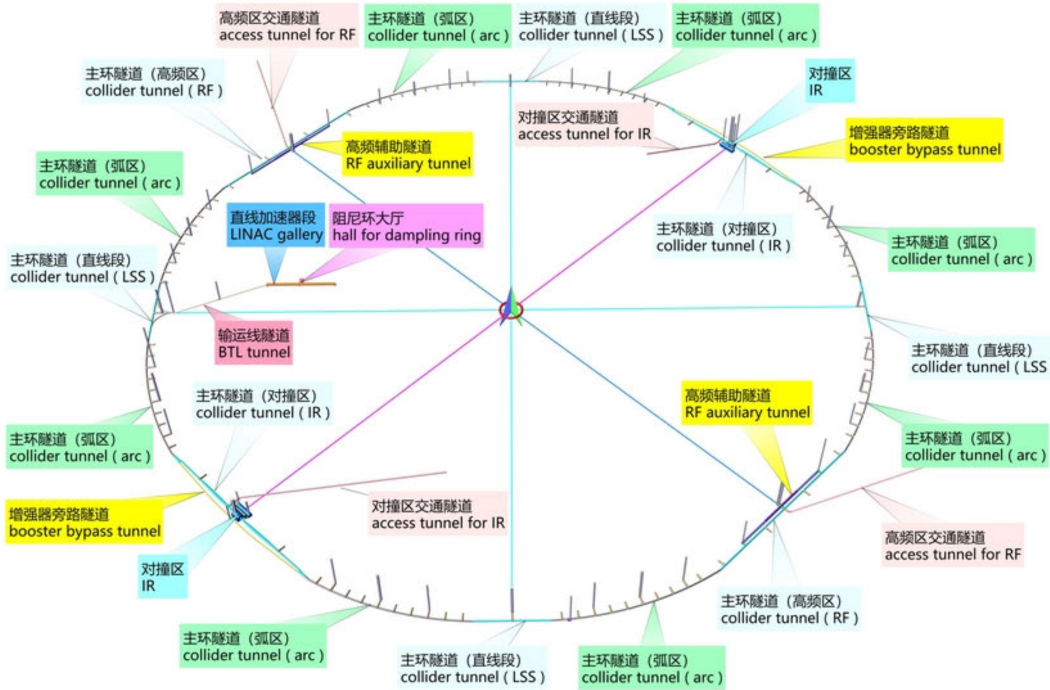

Figure 4: Underground Structure Layouts.

Design of the Underground Structures

- Tunnel shape

Circular, inverted-U, and horseshoe shapes have all been considered for the tunnel cross section. If the TBM method is used, circular will be selected (Fig. 5). If the drill-blast tunnelling method is used, the dimensions will be determined according to construction and transportation requirements during construction, as well as equipment layout and accessibility requirements during installation and operation. The tunnel shape and construction method will be determined through comprehensive technical and economic comparisons. The inverted U-shape (Fig. 6) is selected at this stage.

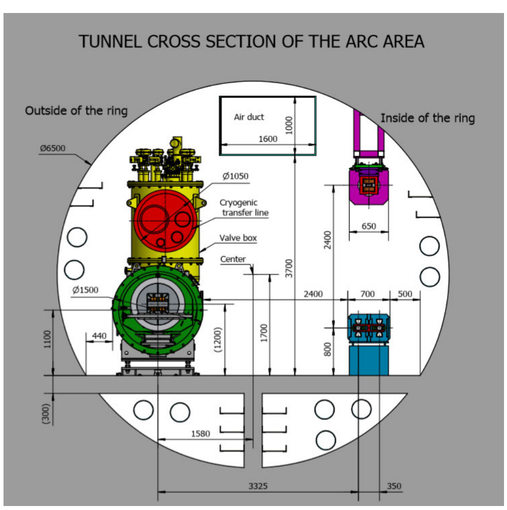

Figure 5: Circular option in the Collider arc section.

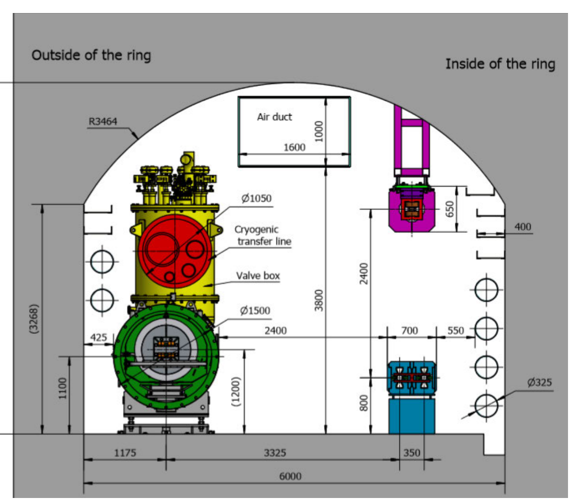

Figure 6: Inverted U-shape option in the Collider arc section.

- Tunnel lining and waterproofing

Waterproofing of the underground caverns is Grade I. Support and lining structures shall meet structural requirements and waterproof requirements. There are the following types of linings: bolt-shotcrete, reinforced concrete, steel fiber concrete and steel structure. Waterproof materials includes waterproof membrane, waterproof coating, rigid waterproof material and concrete admixture. Since the lining structure and waterproof material has a significant economic impact,

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the types of lining structure and waterproof material will be determined through comprehensive technical and economic comparison according to structural and waterproof requirements. At this stage, the following types are considered: drain holes + profiled steel sheets for the crown in Class II surrounding rocks, drain holes + profiled steel sheets for the crown + damp-proof decorative partitions in Class III surrounding rocks, waterproof membranes / boards / coating + 25~50 cm thick waterproof concrete lining in Class IV~V surrounding rocks.

- Shaft structure

Many shafts are distributed around the tunnels. Their size is determined by their functions. For example, the dimension of the transport shaft is determined by the size of the equipment to be transported, pipeline layout, evacuation passage and thickness required for support. The dimension of the shaft for construction and ventilation purposes is determined by construction ventilation requirements.

Sprayed anchor + reinforced concrete lining is used for shaft support. The thickness of shotcrete and lining concrete is determined by shaft diameter and depth, surrounding rock type, groundwater and other factors.

- Experiment halls

The span is large; class I and II surrounding rocks are selected as much as possible for the cavern locations. The region of large geological tectonic belts, fault fracture zones, joint fissure development zones, high in-situ stress zones, goaf zones (where muck has been removed and the space filled with waste) and copious groundwater shall be avoided. The cavern depths should be determined by comprehensive analysis of the lithology, rock mass completeness, weathering unloading degree, in-situ stress magnitude, groundwater situation, construction conditions and experimental requirements and other factors. In general, the overburden thickness should not be less than twice the excavation width of the cavern.

A combination of flexible support and reinforced concrete lining is used due to the small depth of the experiment halls and the strict waterproof requirement. Flexible support is composed of one or several combinations of shotcrete, rock bolt, and anchor cable.

CONSTRUCTION SCHEDULE

The shafts along the tunnel could be utilized for drill and blast construction with multiple working faces proceeding at the same time. With comprehensive comparison from construction technology, construction period and project cost, the drill and blast method is recommended at present. The total construction period is 54 months, including 8 months for construction preparation, 43 months for construction of main structures and 3 months for completion.

The critical path is as follows: construction preparation (8 months, including land acquisition and resettlement, establishing supplies of water, power and compressed air, road connection and communications and site levelling.) → construction of vertical shafts (5 months) → tunnel excavation (24 months) → tunnel lining and waterproofing (10 months) → installation of ventilation equipment and access equipment of the shaft (4 months) → completion (3 months). The construction of surface structures is carried out as the project progresses, and is carried out concurrently with the underground work, so that will not lengthen the construction time line.