Conventional Facilities for CEPC

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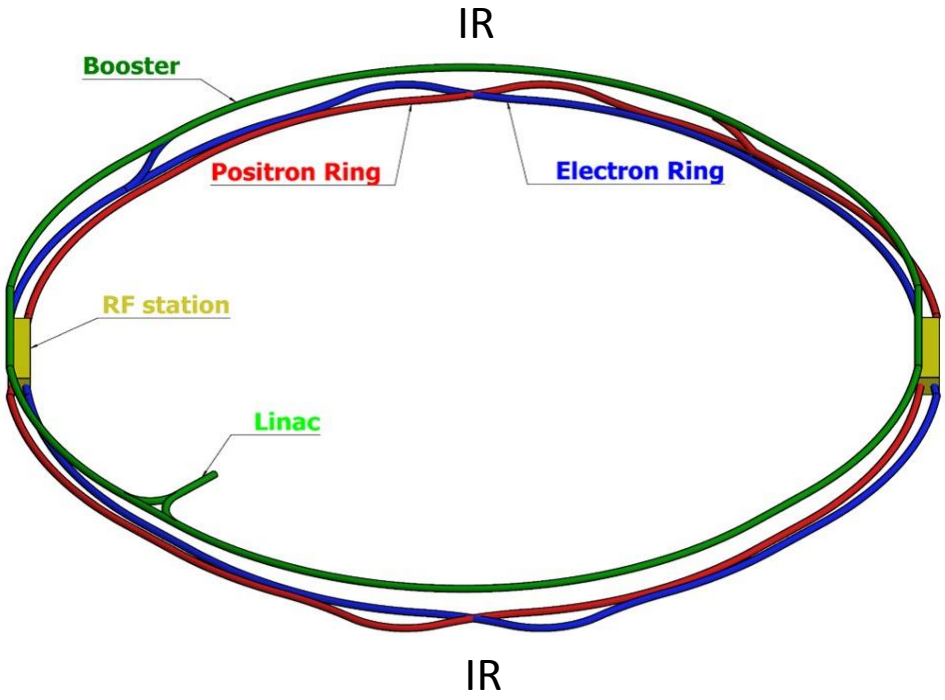
Outline

- Key requirement for buildings
- Site Selection
- CEPC civil works
  - The underground works
  - Surface buildings
- Utilities
  - Electricity distribution system
  - Cooling water
  - HVAC
- Summary

Key requirement

- The main component of CEPC
  - Injector
    - LINAC: 10GeV
    - Beam transfer line (BTL)
    - Booster

      in the same tunnel with ring
  - CEPC ring
    - 2 Interaction regions
      - CEPC detectors (2)
    - 2 RF section
      - RF cavity and cryostat
    - 4 Quadrant section
      - 4 Long straight section, two of them for injection
      - 8 Arc section



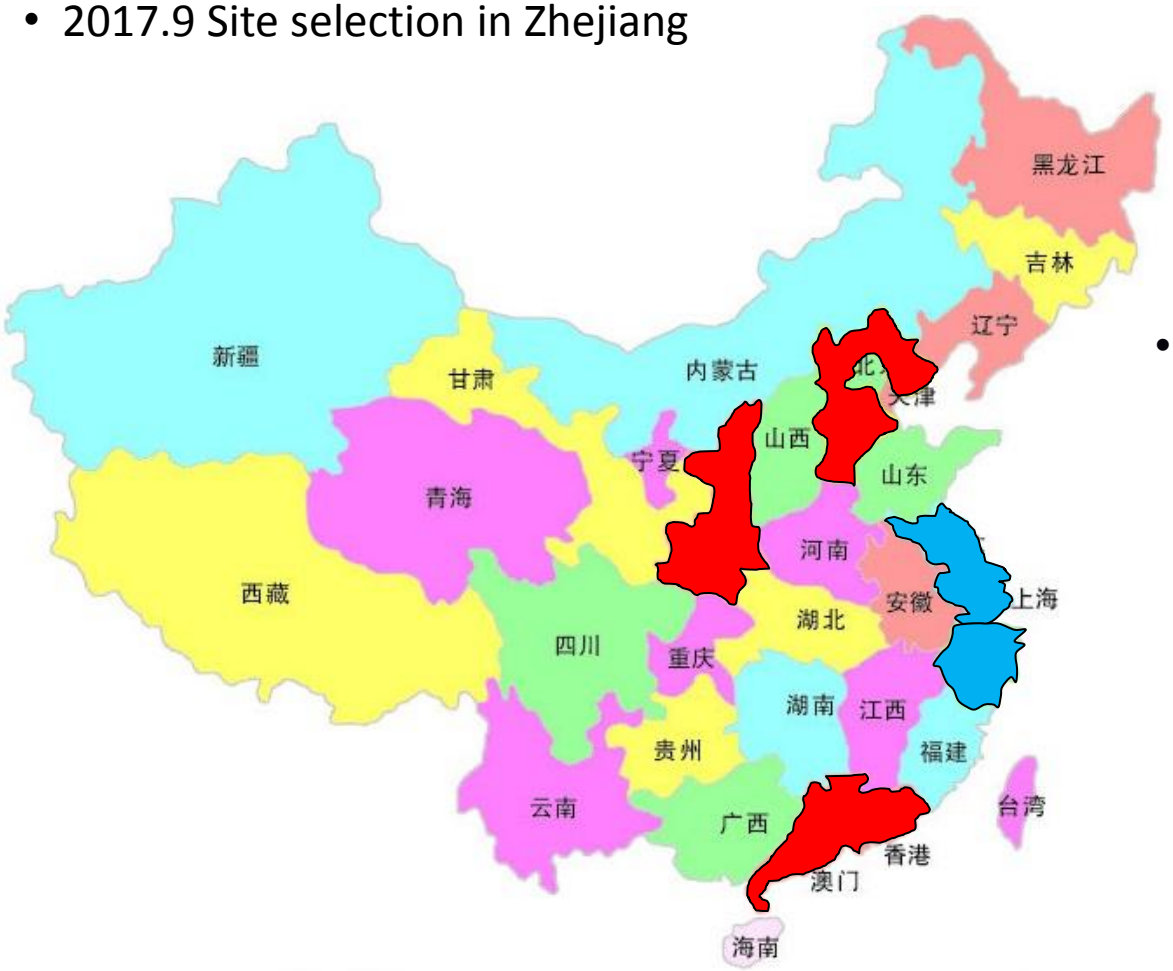
Key requirement（cont'd）

- The key requirement for civil works as follow
  - Ring tunnel
    - Circumference of beam: 100 km
    - To accommodate the main body of CEPC ring and booster
    - Space reserved for sppc in the same tunnel
  - LINAC tunnel
    - Length : 1200m
    - To house Acc. tube
  - Beam transport line
    - Length : (316m + 459m)*2
  - Experimental hall
    - IR1: 30m*30m*30 m
    - IR3: 60m*40m*40 m
  - Surface buildings

    Space requirements are defined by
    - necessary arrangement of equipment housed within the buildings (power converter, cryogenics compressor, utilities, etc.)
    - service access requirements
    - entrance and egress requirements for operational personnel.

Site selection

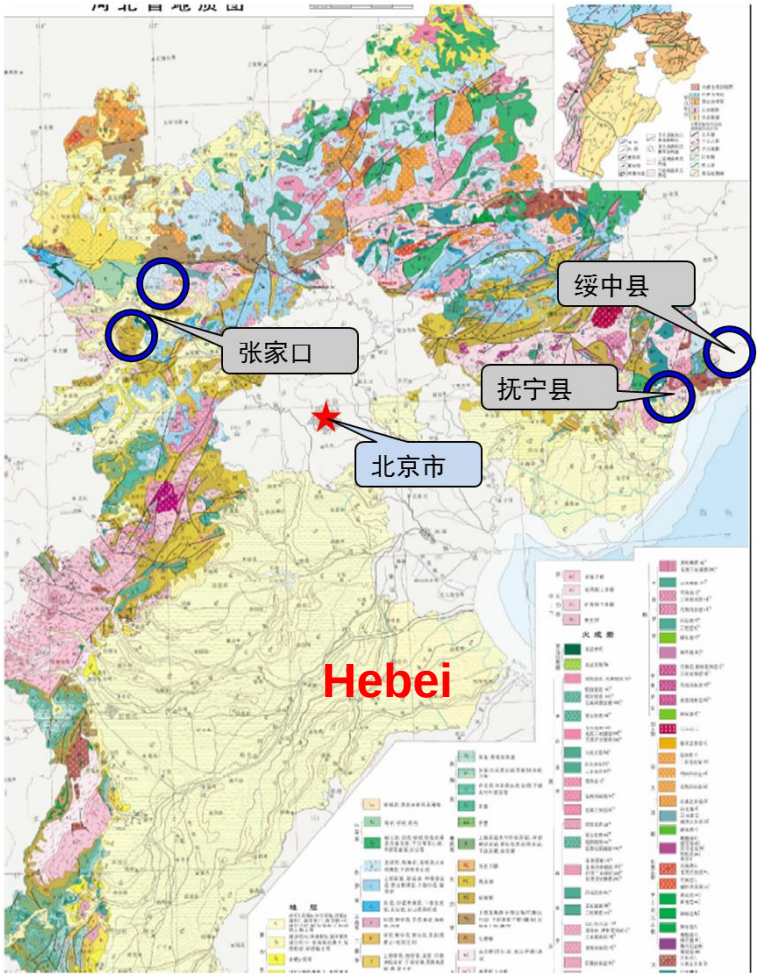
- 2014.4~2015.3 Site selection in Hebei
- 2014.5~2016.8 Site selection in Guangdong
- 2014.6~2017.7 Site selection in Shaanxi
- 2016.9 Site selection in Jiangsu
- 2017.7~8 Site selection in Baoding City, Hebei Province
- 2017.9 Site selection in Zhejiang

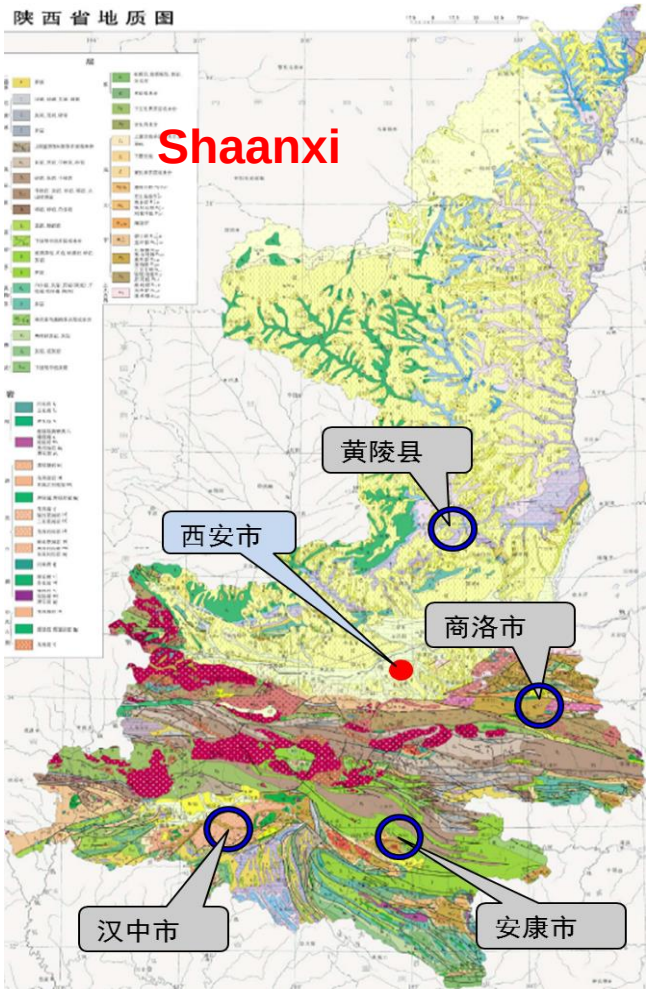


- During the time from 2014 to 2017, we made preliminary comparison and selection of the sites in the provinces of Hebei, Guangdong, Shaanxi, Jiangsu and Zhejiang.
- And conducted field investigation in Hebei, Guangdong and Shaanxi.

Site selection（cont'd）

YREC

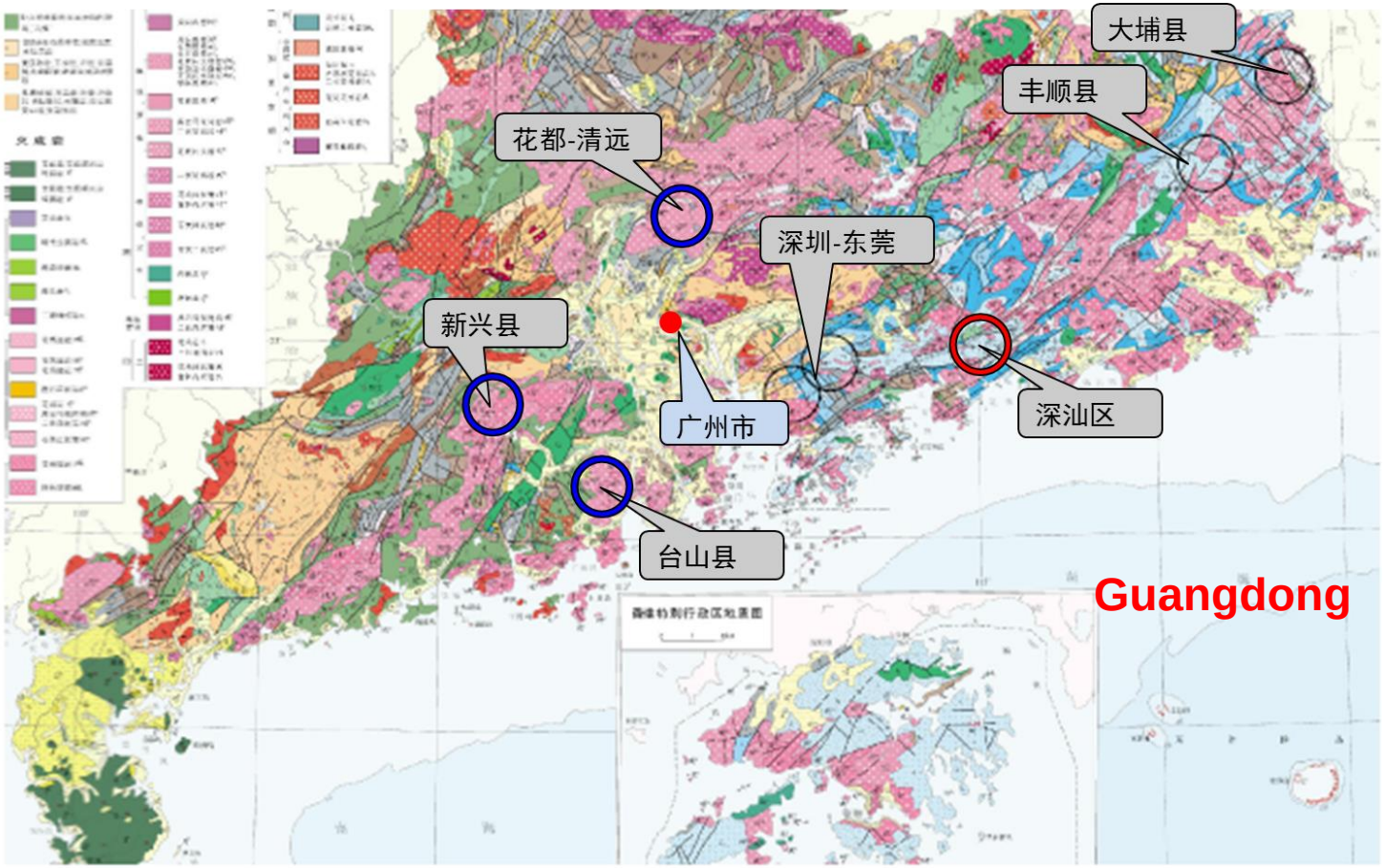




Hebei: With respect to the topographical and geological conditions, Zhangjiakou basin, the area nearby Funing County and the area of Shanhaiguan–Suizhong County are studied and compared.
Shaanxi: Southern Huangling County, Northeastern Shangluo City, Eastern Hanzhong City, Northern Ankang City are studied.

Site selection（cont'd）

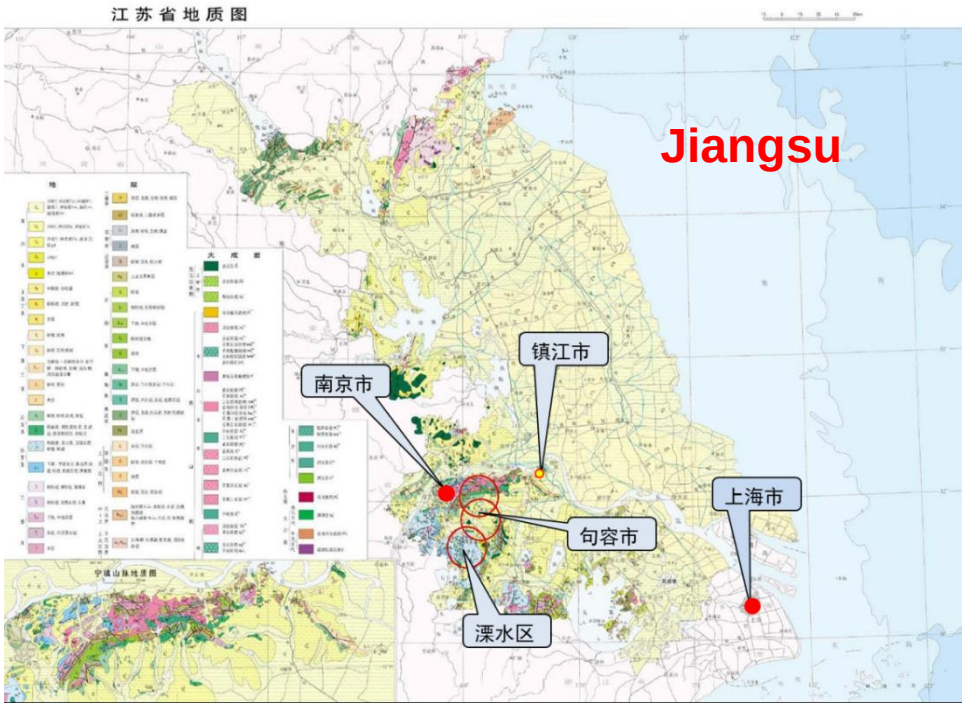
YREC

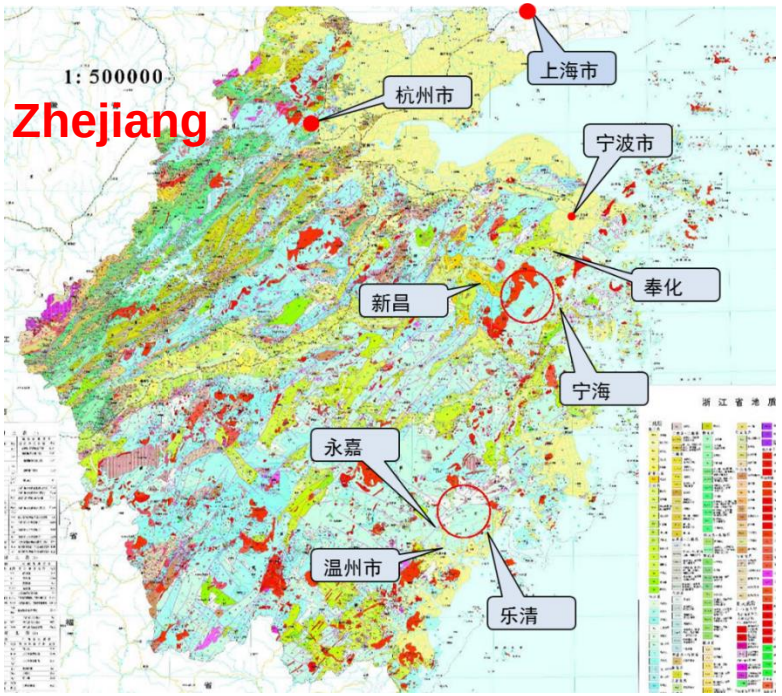


Guangdong: With respect to topographical and geological conditions in Guangzhou, the areas of north of Huadu-east of Qingyuan, the area surrounding Taishan, the area of east of Xinxing County are compared; Dapu County of Meizhou, north of Fengshun County and the area of Shenzhen-Dongguan are also compared. From September of 2015 to August of 2016, as required by Shen-Shan District and IHEP, Shen-Shan Special Cooperation District was selected for site comparison.

Site selection（cont'd）

YREC

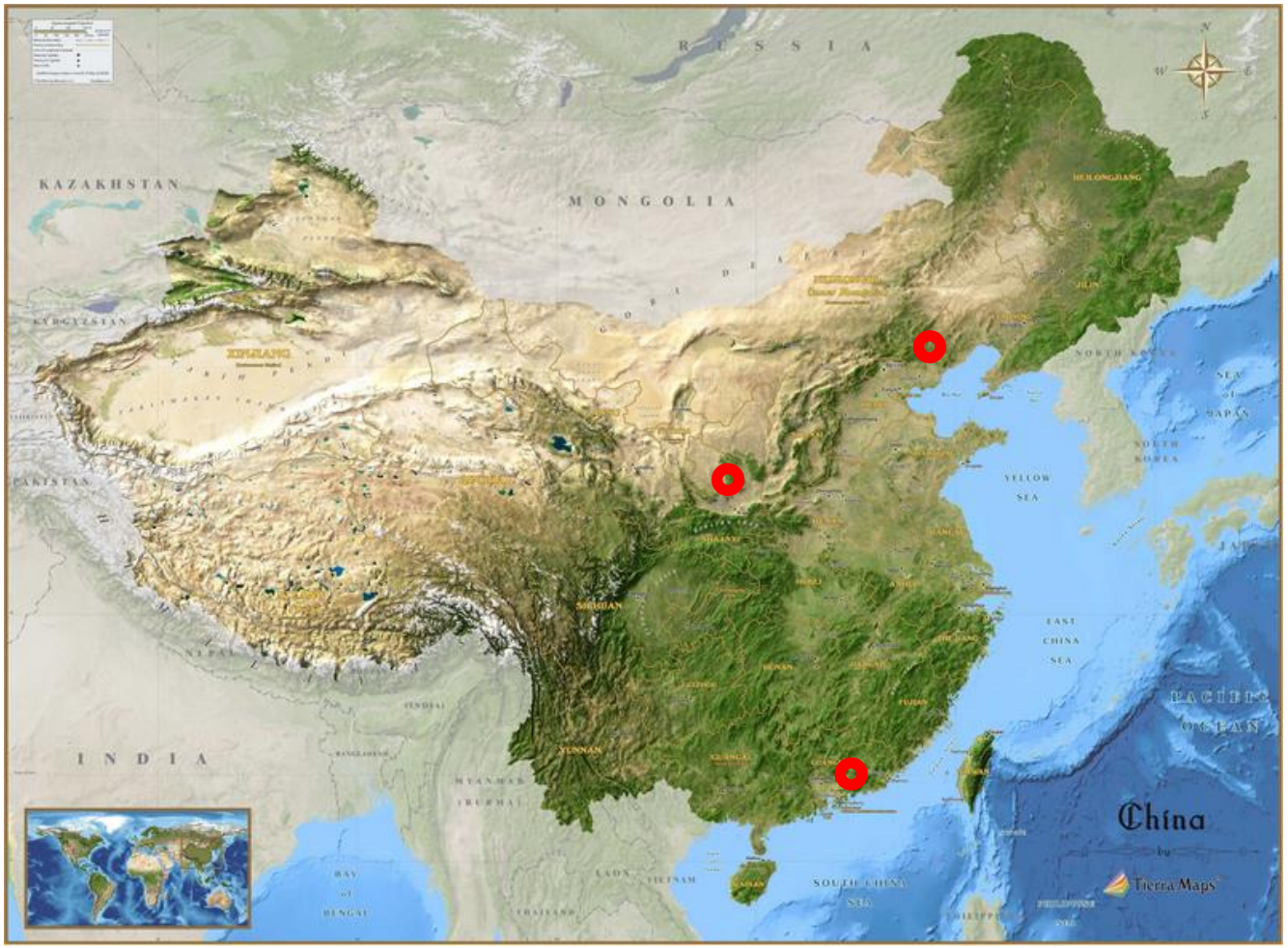




Jiangsu: Areas along Eastern Zijin Mountain– Jurong City – Lishui District were chosen to be the location areas.

Zhejiang: The initial selection of Fenghua - Ninghai - Xinchang in the eastern part of Zhejiang Province and the northern area of Yongjia - Yueqing as the location area.

Site selection（cont'd）



According to the requirements of CEPC and local government, Funing, Shen-Shan and Huangling were selected for site comparison.

Site selection（cont'd）

YREC

Geological exploration at Funing, Hebei Province




Topography and landforms




Stratum Lithology





Drill Holes

Site selection（cont'd）

YREC

Geological exploration at Shen-Shan, Guangdong




Topography and landforms







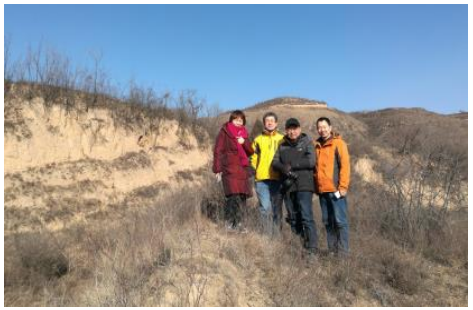
Drill Holes

Site selection（cont'd）

YREC

Geological exploration at Huangling, Shaanxi



Topography and landforms



Stratum Lithology



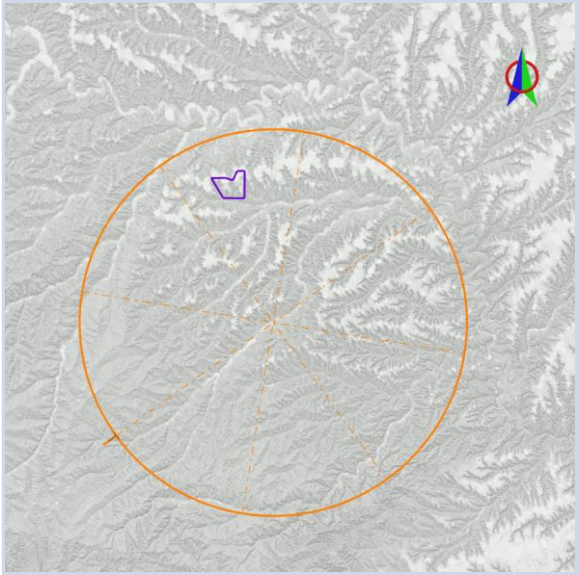
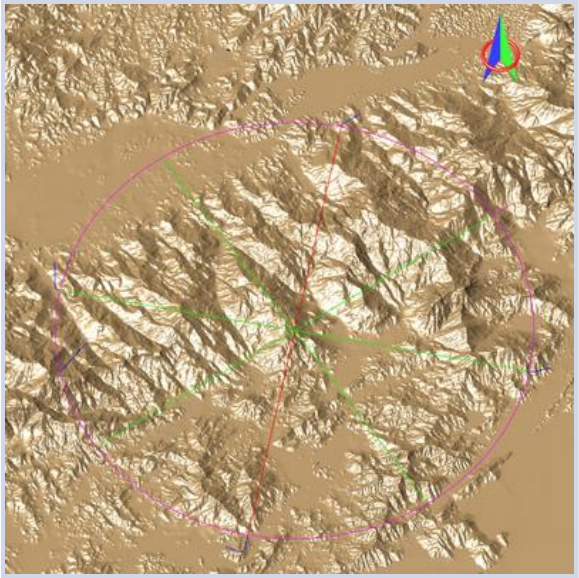
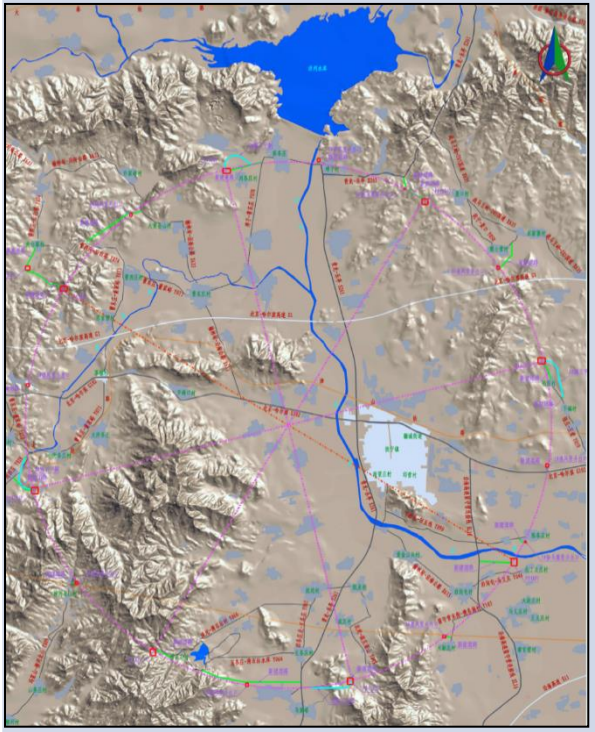

Drill Holes

Site selection（cont'd）

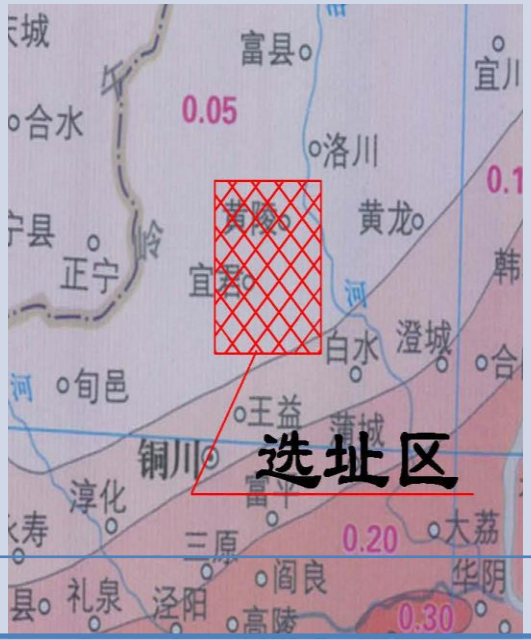
YREC

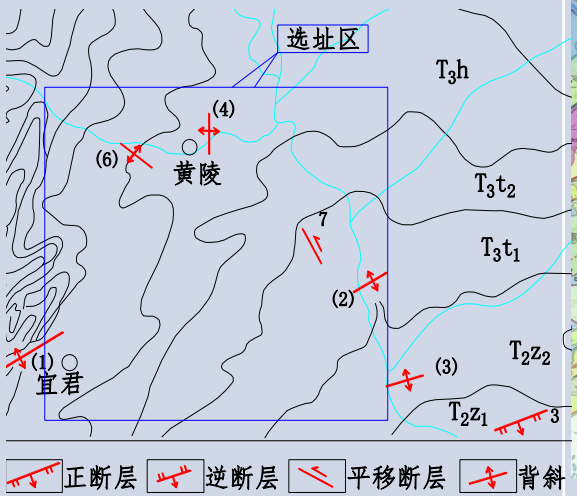
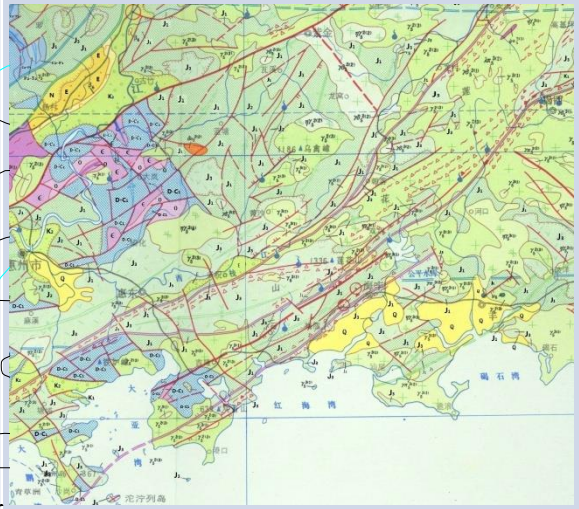
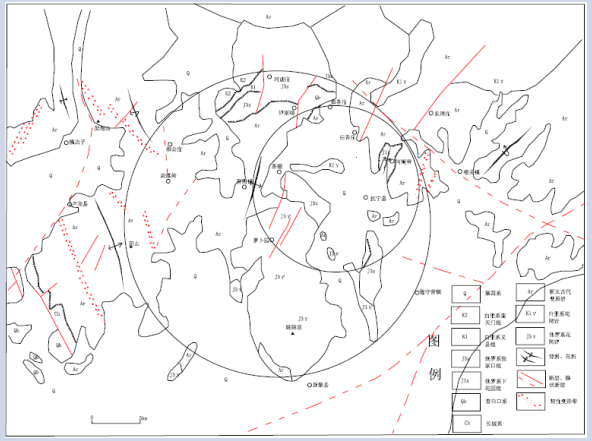
- Based on geological exploration data, we made preliminary comparison of the sites which have been investigated in the respects as follow:
  - Location
  - Topography and landforms
  - Stratum Lithology
  - Geological structure
  - Hydrogeology
  - Surrounding rock classification
  - Main engineering geological problems
  - Tunnel profile and construction
  - Cost.

Item		Huangling	Shen-Shan	Funing
Construction conditions	Location			

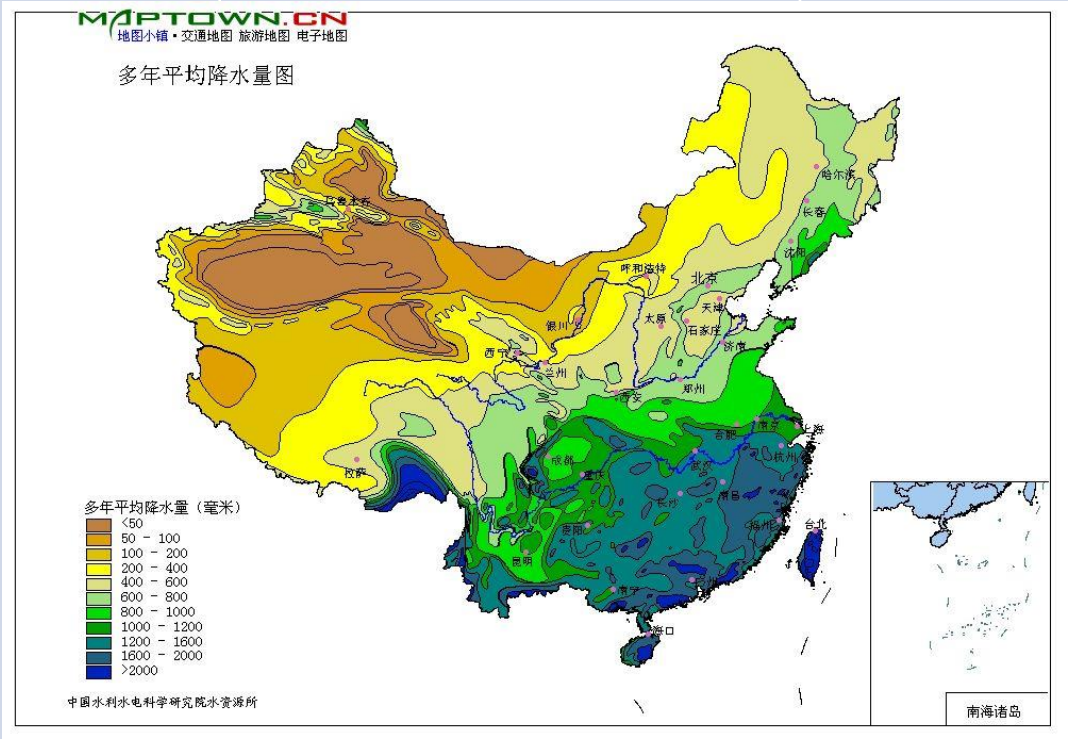
Item	Huangling	Shen-Shan	Funing
Geological and topographical conditions			
Topography and landforms	 The site is in the gully area of loess plateau and the overall terrain is generally high in west and low in east with an elevation of 600~1600m. The terrain relative maximum height difference is about 1000m, so the terrain is broken.	 The site is located in the Valley geomorphic area. The middle is high and the north and south are lower. The ground elevation varies largely, generally 20~800m. The highest peak of Mount Lianhua is up to 1336m.	 The site is in hilly area. The elevation of most places is 20~200m. The highest elevation is 695m.

Item	Huangling	Shen-Shan	Funing
Geological and topographical conditions Stratum Lithology	 Bed rock covered with loess  Alternative layers of sandstone and shale	 Rhyolite  Granite  Sandstone Intercalated with shale  Sandy Gravel	 Gneiss  Granite

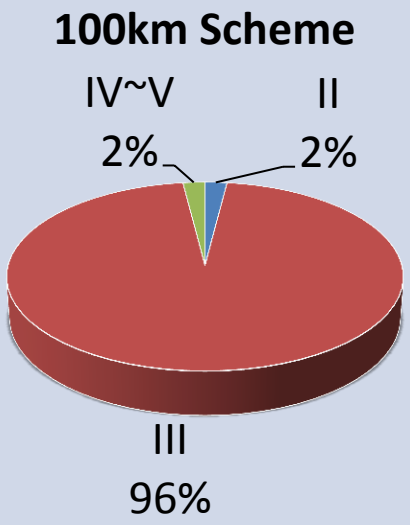
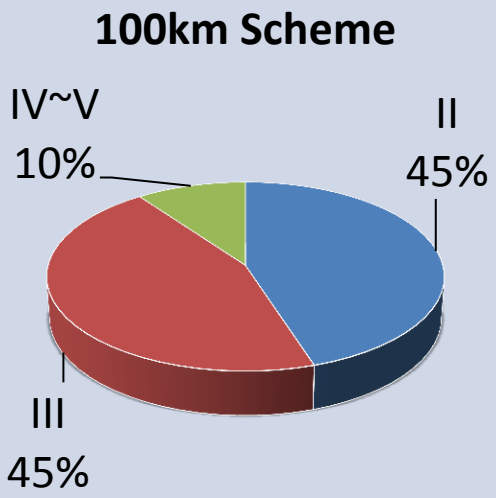
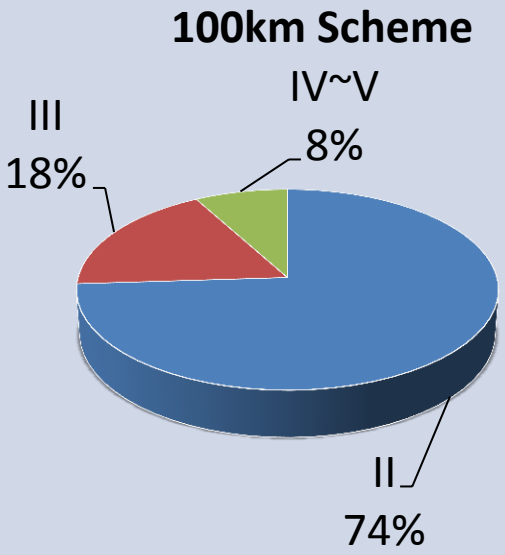
Item	Huangling	Shen-Shan	Funing
Geological and topographical conditions			
Geological structure	**Earthquakes**		
	There are no active faults and earthquake activity that is over magnitude-4.75 within 25km of the site.	There are no active faults and earthquake activity that is over magnitude-4.75 within 25km of the site.	There are no active faults within 5km of the site, and there is seismic activity at moderate intensity level but without strong earthquake activity.
		Seismic peak acceleration	
	0.05g	0.05~0.10g	0.10~0.15g
		Basic seismic intensity	
	<VI	VI~VII	VII

Item	Huangling	Shen-Shan	Funing
Geological and topographical conditions Geological structure			
	The geological structure is simple within the selected site area.	The Mount Lianhua fault zone goes across the site from northeast to southwest. The fault zone is composed of multiple fractures.	There is no large fault zones in the site area.

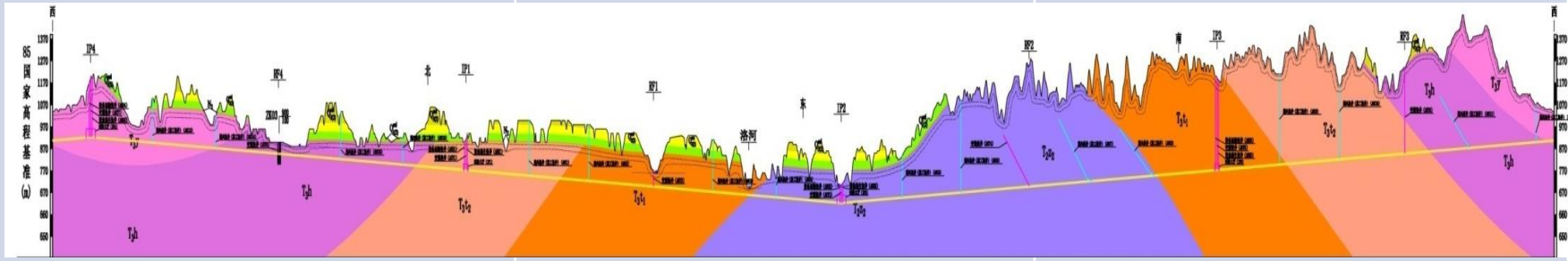
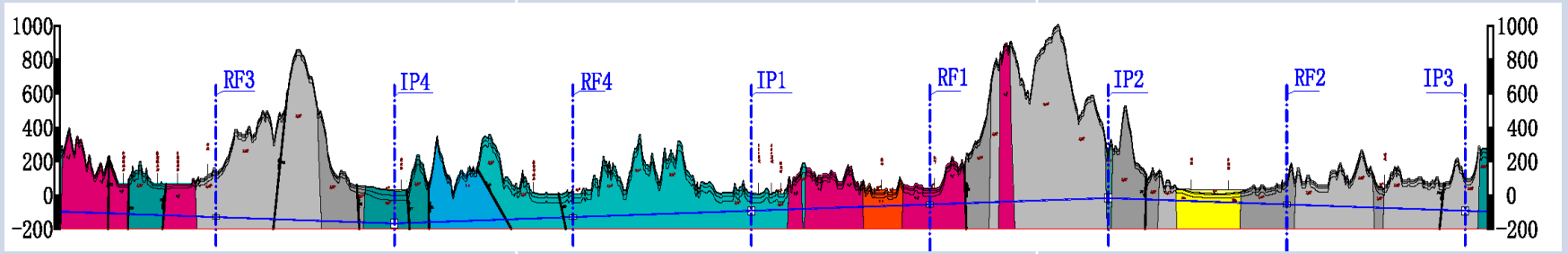
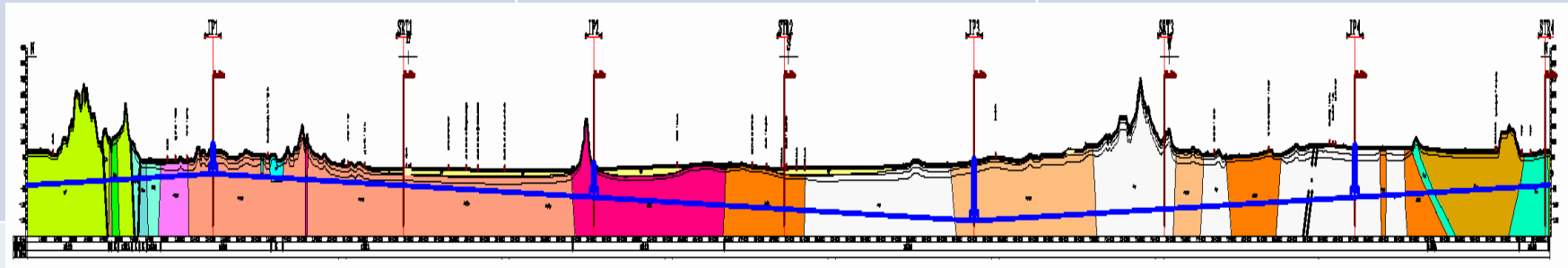
Item	Huangling	Shen-Shan	Funing
Geological and topographical conditions			
Hydrogeology			



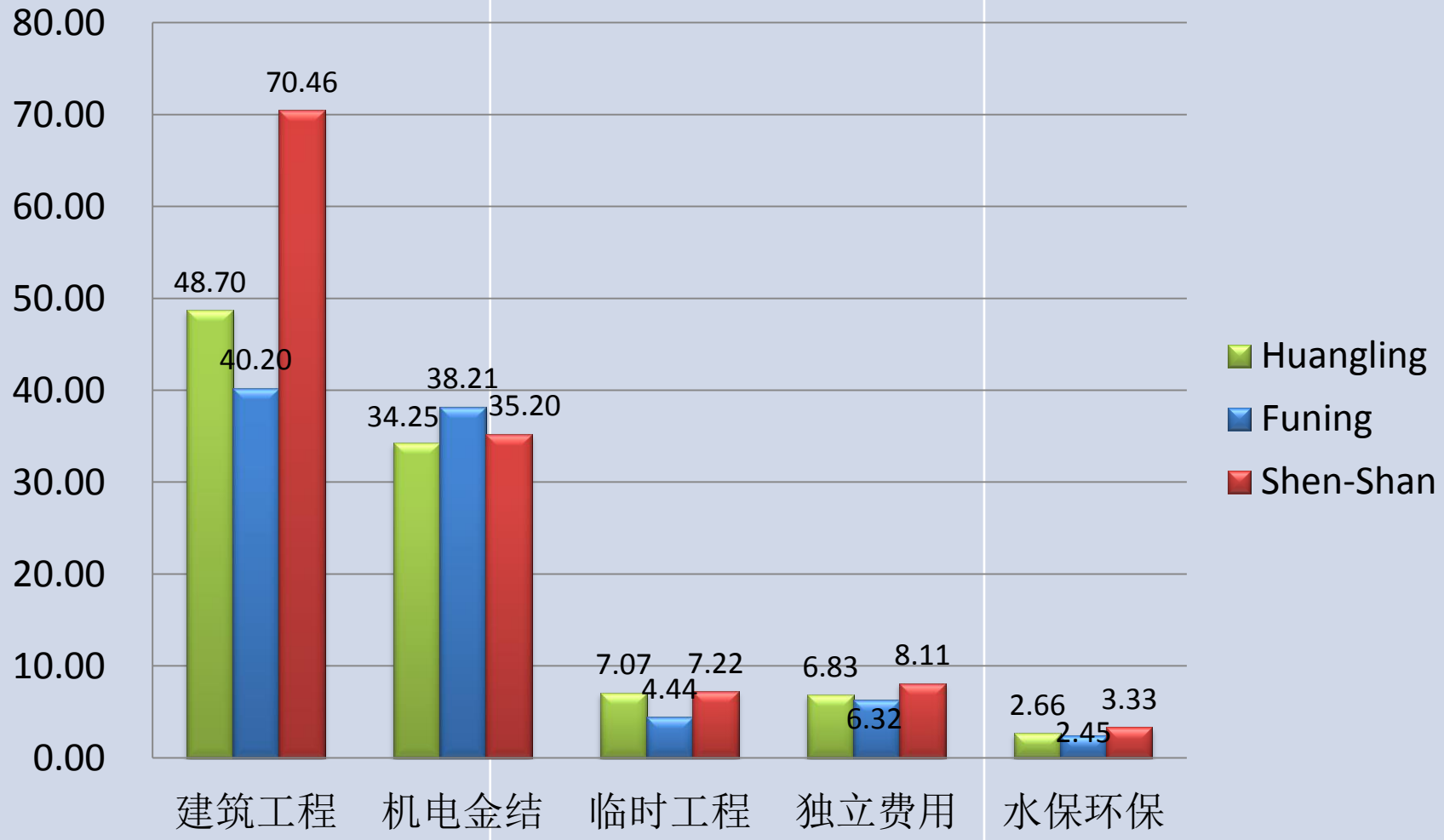
Annual mean precipitation		
577~709mm	2214mm	684mm
Rock mass perviousness		
Most slightly weathering-fresh rock mass is mainly slightly pervious.	Slightly weathering-fresh rock mass is mainly slightly pervious. The perviousness is controlled by fractures.	Slightly weathering - fresh rock mass is mainly slightly pervious. The perviousness is controlled by fractures.

Item		Huangling	Shen-Shan	Funing
Geological and topographical conditions	Surrounding rock classification	 The surrounding rock are mainly Class III; the local sandstone is mainly Class II; the surrounding rock mainly consist of the shale and mudstone are Class IV; the surrounding rock in the fault zones and joints are Class V.	 The fresh granite is mainly Class II, the volcanic rocks are Classes II and III; the clastic surrounding rock is mainly Class III; the surrounding rocks of the red rock are preliminarily classified as Classes IV-V.	 The classification of fresh granite, gneiss and tuff rock are mainly Class II, and some sandstone are mainly Class III. The tunnel is dominated by Class II surrounding rock, and the main hall is Class II surrounding rock.

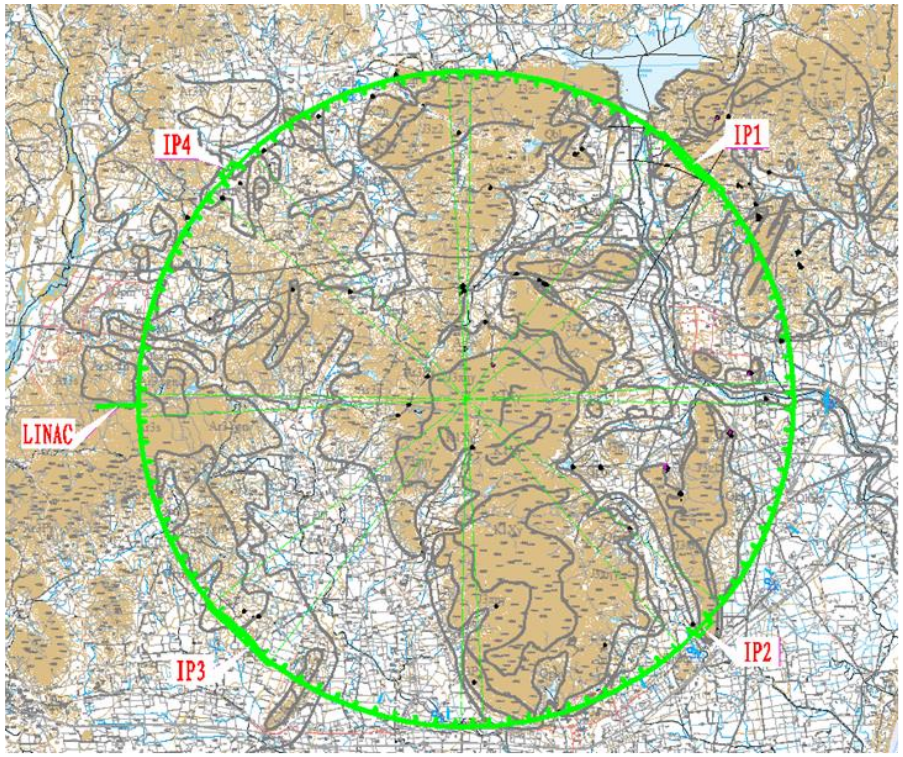
Item	Huangling	Shen-Shan	Funing
Geological and topographical conditions Main engineering geological problems	 Local sandstone contains oil.  Noxious gas	 Water inflow  High geostress  High ground temperature  Soft rock	 Gushing water while across Yanghe River

Item	Huangling	Shen-Shan	Funing
Project layout	Huangling（100km） 	Shen-Shan（100km） 	Funing（100km） 
Construction difficulty	Moderate	Relatively difficult	Relatively easy

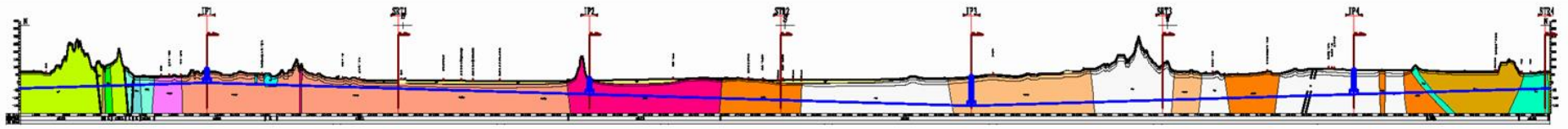
Item	Huangling	Shen-Shan	Funing
Cost Estimation	100km: 10.92 billion RMB	100km: 13.64 billion RMB	100km: 10.06 billion RMB



The favorable site is Funing



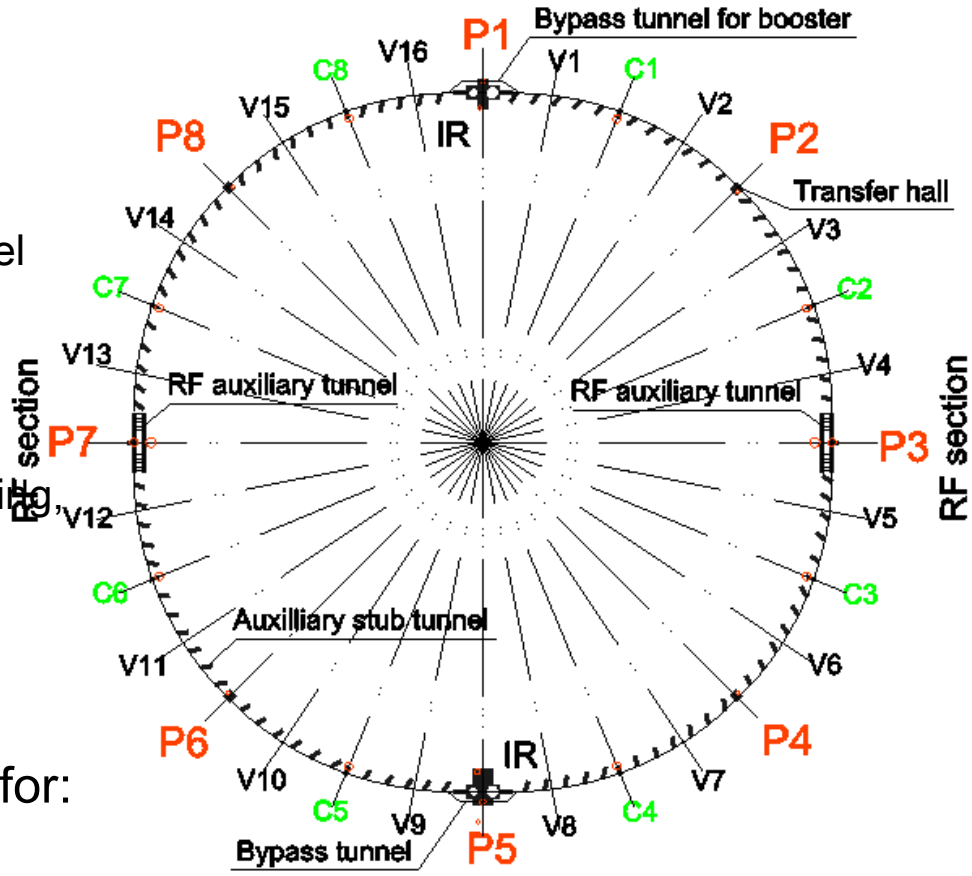
Based on the terrain and geological conditions, Funing site is the best among current three sites, followed by Huangling and Shen-Shan. But in general, all the sites are suitable for the underground construction of such a large extent. The main geological problems encountered can be solved by engineering measures.



The depth from ground level of ring tunnel is about 60-240m（ 400m at hill） according to topographical conditions. At the places for IR and main access shaft the depth is about 60m- 190m.

Layout of CEPC civil works

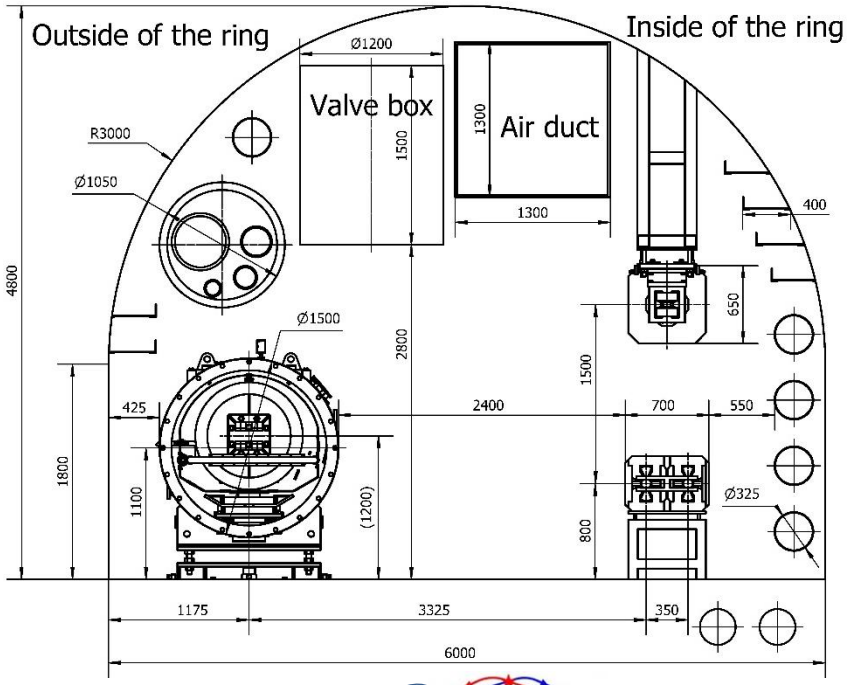
- Underground works
  - 100km ring tunnel
    - 4 Quadrant of ring tunnel
    - 2 RF section + RF auxiliary tunnel
    - 2 Interaction regions + bypass tunnel
  - 96 auxilliary stub tunnel
- Ground level (32 places)
  - P1, P5 service building for:
    - Detectors facilities, convertors, cooling, ventilation, electricity, access
  - P3, P7 service building for:
    - RF power source, cryogenics, convertors, cooling, ventilation, electricity, access
  - P2, P4, P6, P8 service building for:
    - convertors, cooling, ventilation, electricity, access
  - C1-8 service building for:
    - cooling, ventilation, electricity, access
  - V1-16 service building for:
    - Ventilation (air exhaust)

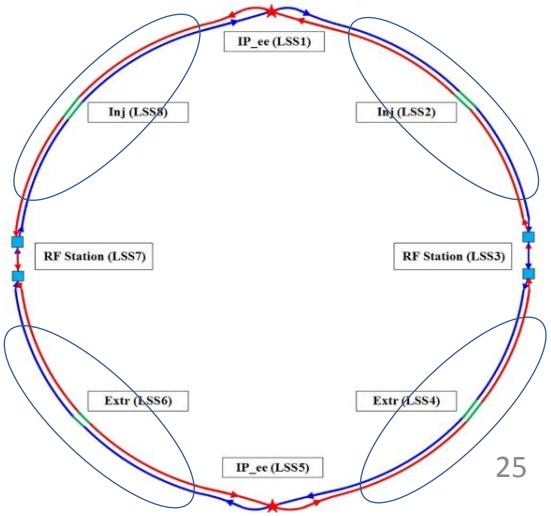


- Installed on an inclined median plane with a slope of 0.3% according to the topographical conditions and the drainage requirements
- The depth of ring tunnel from ground level is defined by topographical conditions of site

Underground works

- Quadrant of ring tunnel
  - Normal inner diameter: 6m
  - Height: 4.8m
  - Tunnel cross-section is divided into three parts
    - CEPC ring: inside of the tunnel
    - CEPC booster: on the top of CEPC ring
    - SPPC: outer side of the tunnel
    - Middle area: for handling and transporting equipment

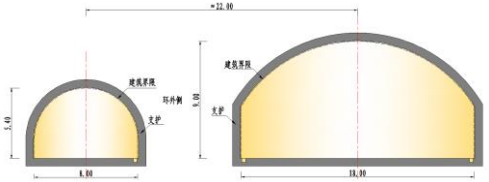


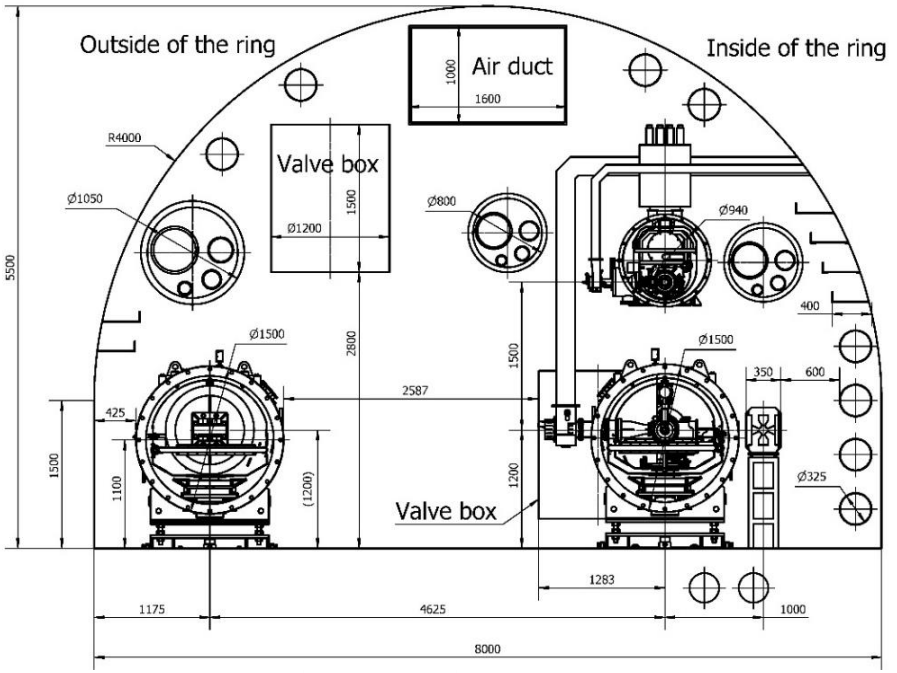


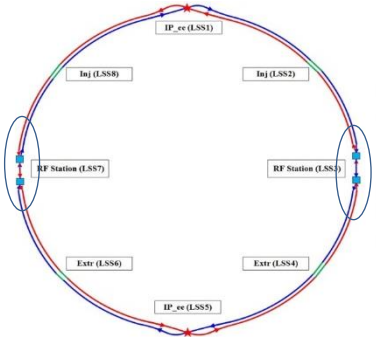
Description	Quantity	Specification
Arc tunnel length	**2*4**	**10.4065 km**
Arc radius		**15.9km**
Long straight section tunnel length	**4**	**1125m**

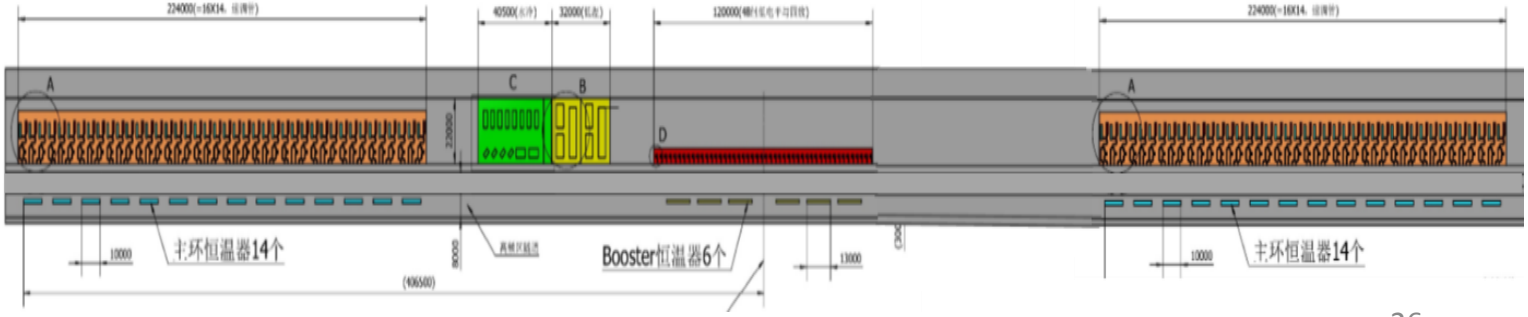
Underground works（cont'd）

- RF section tunnel
  - Normal inner diameter: 8m
  - Height: 5.5m
- RF auxiliary tunnels (2),
  - parallel to RF section tunnel
  - To accommodate klystron, circulator, waveguide, coldbox, utilities, etc. closed to cavity and cryostat
  - Booster RF in the same tunnel
  - Length: 900m
  - Width: 18m; Height: 9m

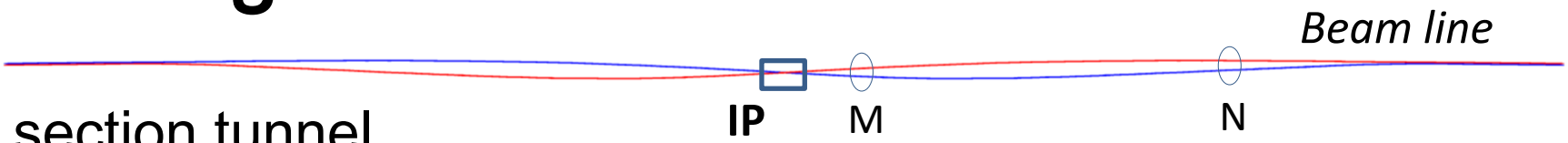






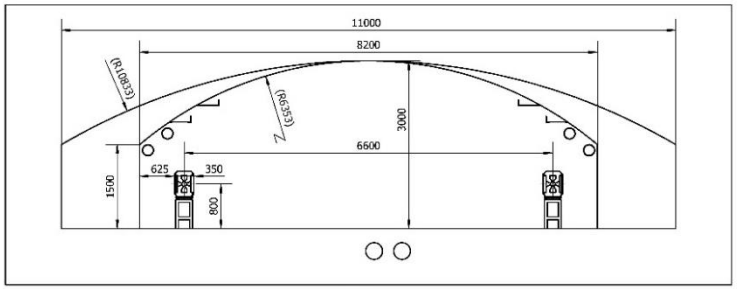


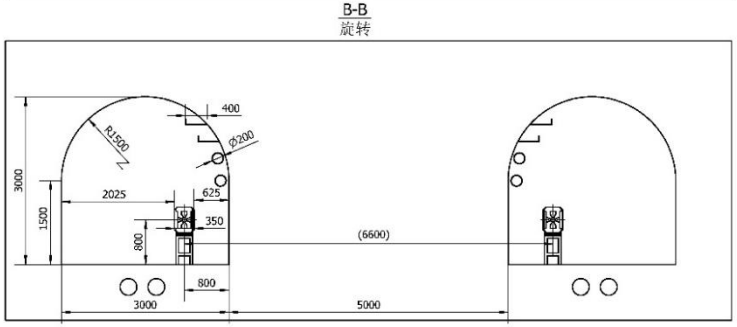
Underground works（cont'd）

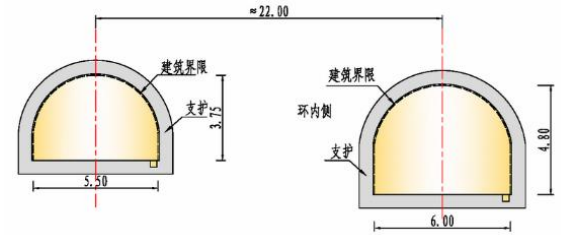


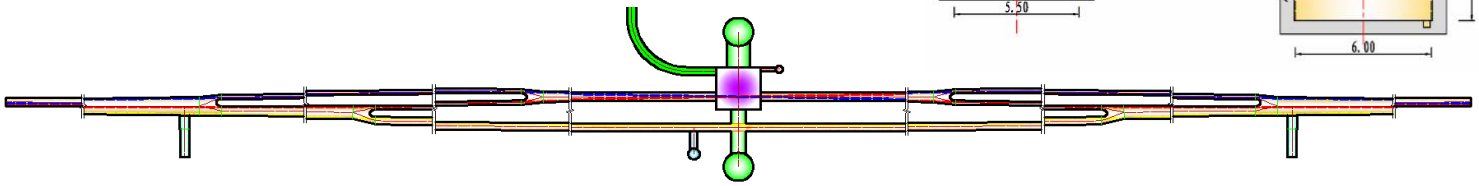
- IR section tunnel
  - Experimental hall
    - IP1: 30m*30m*30m
    - IP3: 60m*40m*40m

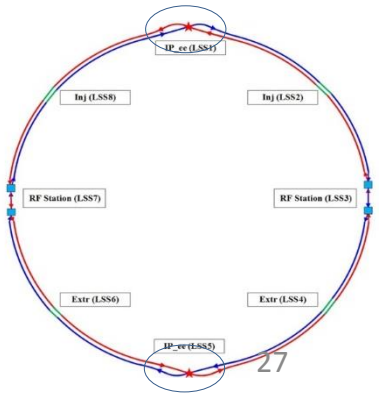
    The detailed dimension not defined now
  - Tunnel inner diameter
    - Tunnel enlargement,
    - M: branched into two line: 3m*2
    - N: merged to one tunnel, then contracted to normal diameter
  - Bypass tunnels
    - Dedicated to bypass detector for booster in interaction region
    - Tunnel inner diameter: 3m





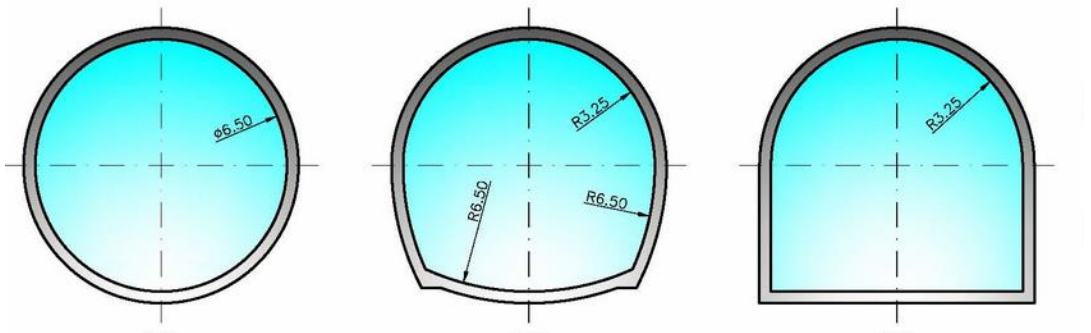


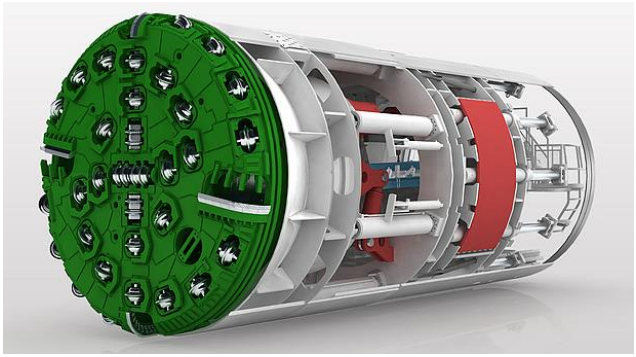




Underground works（cont'd）

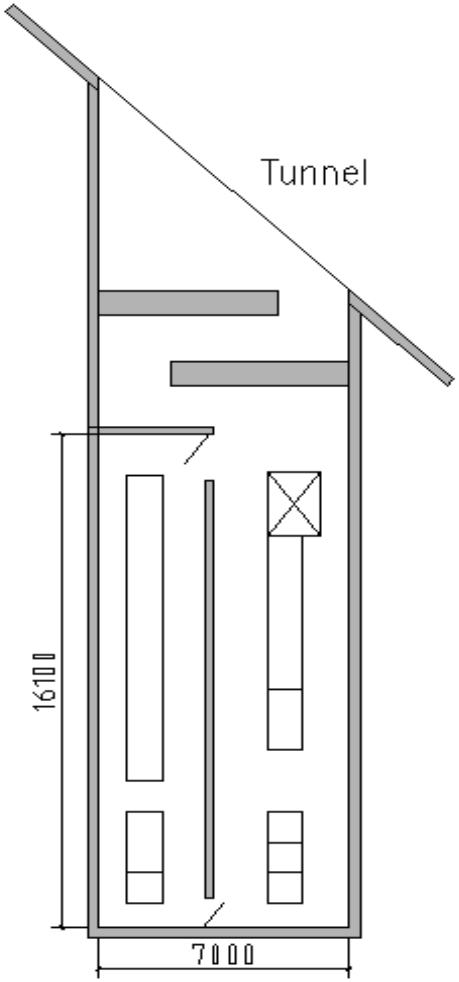
- Cross section shape of tunnel
  - Portal-shaped
    - Construction with drilling & blasting method
    - Cheaper than TBM at present
  - circular section
    - TBM (Tunnel boring machine) may be selected.
  - The proper shape and dimensions of cross sections will be determined and optimized based on a comprehensive technical and economic comparison. Now cost estimation is based on portal-shaped.





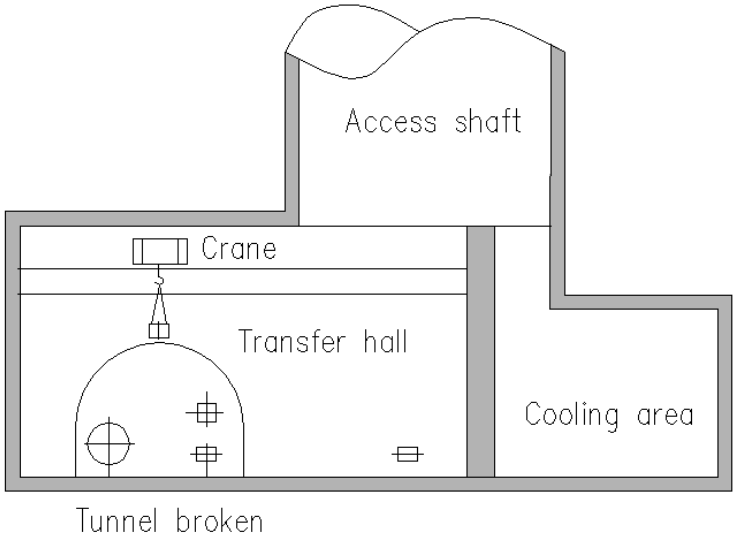
Underground works（cont'd）

- Auxiliary stub tunnel
  - To house electric substation, cabinet for vacuum, diagnostic, local control, and HVAC, UPS etc.
  - Inner diameter: 7m
  - 96 cavern arranged around ring tunnel
  - Service distance: about 500m
- Underground areas for cooling water system at P1-8, C1-8 (16)
  - Floor area size: 200m^2×16



Underground works（cont'd）

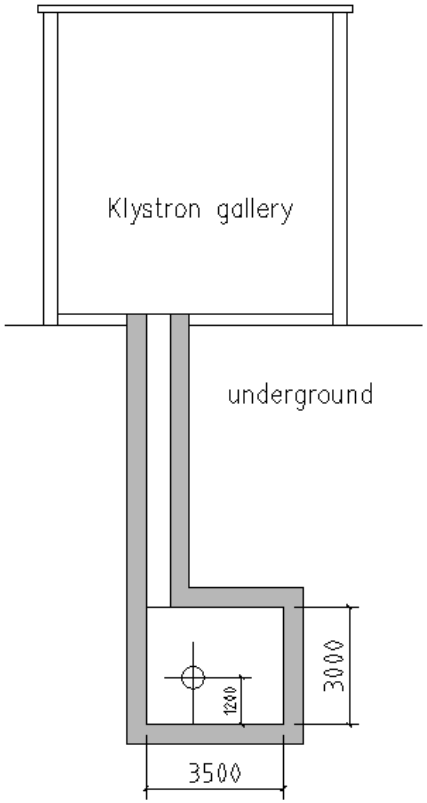
- Access shafts for ring tunnel
  - Function
    - Transport staff and equipment into the ring tunnels.
    - Cable, pipe, duct, etc.
    - Emergency exit
  - One of Φ20m at RF auxiliary tunnel
  - Two of Φ 20m and one of Φ5m at experimental hall
  - One of Φ10m at P2, P4, P6, P8
  - One of Φ 8m at C1-8
  - Two of Φ 5m at transport line tunnel
  - One of Φ 5m at V1-16

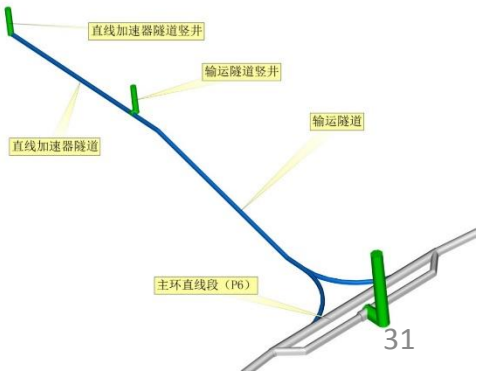


- There are magnets or cryostats at each side of tunnel. How to transport equipment?
- At each points, transfer hall is inserted into tunnel where tunnel wall is open.
- The equipment is loaded into transfer hall via shaft, which will be lifted into the middle area of tunnel by crane

Underground works（cont'd）

- LINAC tunnel
  - Length: 1200m
  - Cross section: 3.5m*3m
  - The depth from ground level: about 5m, shielding layer.
  - Klystron gallery is above the tunnel at ground level
- BTL tunnel
  - Cross section: 3.5m*3m
  - About 316m long, branched two way, and sloped from LINAC to booster level.
  - Two 459m long tunnel connected to booster in two different direction.





Surface buildings

- Ring surface buildings
  - Service buildings for power converters, local control room, electronics room, helium compressor, utilities, etc.
    - Arranged to be closed to access shaft of ring tunnel at each place
- LINAC surface buildings
  - The klystron gallery
    - Right above the LINAC tunnel.
    - 7m*1200m
  - Service buildings for magnets power supplies, local control room, cooling water , HVAC, electric distribution, etc.
    - Arranged to be in both sides of the klystron gallery.
- BTL surface buildings
  - Service buildings for magnets, power supplies, local control room, cooling water , HVAC, etc.
    - At the end of LINAC
- Detectors service buildings in IR

Surface buildings（cont'd）

Purpose	location and floor area size of building (m^2)												Total (m^2)
	P1	P2	P3	P4	P5	P6	P7	P8	C1-8	V1-16	LINAC	BTL	
	IR	LSS	RF	LSS	IR	LSS	RF	LSS	*8	*16			
Control / duty rooms	1200	300	300	300	1200	300	300	300			400		4600
Power converter for magnets	2000	1500	1500	1500	2000	1500	1500	1500			500	400	13900
RF			4000				4000				8400		16400
110 kV electric substation	1500	1500	2500	1500	1500	1500	2500	1500					14000
10 kV electric substation	600	500	1000	500	600	500	1000	500	2400	3200	400		11200
HVAC	800	600	800	600	800	600	800	600	4800	3200	600	300	14500
Cryogenic (helium compressor)	1000		4000		1000		4000						10000
Cooling water system	800	600	1500	600	800	600	1500	800	3200		500	200	11100
Experimental assembly work	1500				1500								3000
Magnet assembly and calibration	3000												3000
Unloading equipment	200	200	200	200	200	200	200	200	1600		200	150	3550
Compressed air	150	150	150	150	150	150	150	150			150		1350
Chilled water	1500	1200	1200	1200	1500	1200	1200	1200	8000		500		18700
Electronics room	1000	600	600	600	1000	600	600	600			450	100	6150
Other	500	500	500	500	500	500	500	500	2400	2400	200		9000
Total	15750	7650	18250	7650	12750	7650	18250	7850	22400	8800	12300	1150	140450

Campus office buildings not included

Surface Buildings at **IR**

YREC

Electrical distribution system

- Electric power demand estimated for CEPC

System	Location and electrical demand(MW)						Total (MW)
	Ring	Booster	LINAC	BTL	IR	campus	
RF power source	160	7.68	1.75				169.43
Cryogenics	16.8						16.8
Converter for magnets	98.5	10.5	5.7	2			116.7
Experimental devices					14		14
Dedicated services	6	3	1	0.5			10.5
Utilities	40		2	0.5	3		45.5
General services	13		1	0.3	1	12	27.3
Total	334.3	20.18	11.45	3.3	18	12	**400.23**

Electricity distribution system（cont'd）

- Electric power demand reduction

  Since the last review, electric power demand is reduced from 500MW to ~400MW although tunnel is doubled

  – SR power: 50MW*2 → 30MW*2
    - RF power source
    - Cryogenics
    - Cooling system
  – Twin aperture dipole for collider
    - Magnet power not doubled, although tunnel is twice long
  – Campus power demand is cut down
  – To optimize technical requirements
    - Booster magnet aperture
- Further electrical power reduction →**350MW**

  Supposing that：
  - Klystron efficiency ↑(higher)
  - Cable loss ↓ (lower)
  - Magnet aperture ↓ (optimized)
  - ……

Electricity distribution system（cont'd）

- Layout of electric distribution on the site
  - The voltage levels on the site:
    - 220kV incomer of CEPC master substation
    - 110kV power distribution system,
    - 10kV power distribution system for HV power equipments and step-down substation incomer
    - 0.4kV power distribution system for dedicated and general services
  - 220/110kV Master substation
    - 220kV feeds connected to grid station nearby (State Grid Corporation of China)
    - Rated capacity of transformer: 4*180MW (220/110kV)

Electricity distribution system（cont'd）

- 110/10kV step-down substations
  - located at points (P1-8)
  - Two 110kV feeds from master substation
  - Rated capacity of transformer:
    - RF points: 120MW (110/10kV)*2
      - Load:~120, or 135MW
    - IR points: 31.5MW*2
      - Load: ~36MW
    - Other points: 20MW*2
      - Load: ~25MW

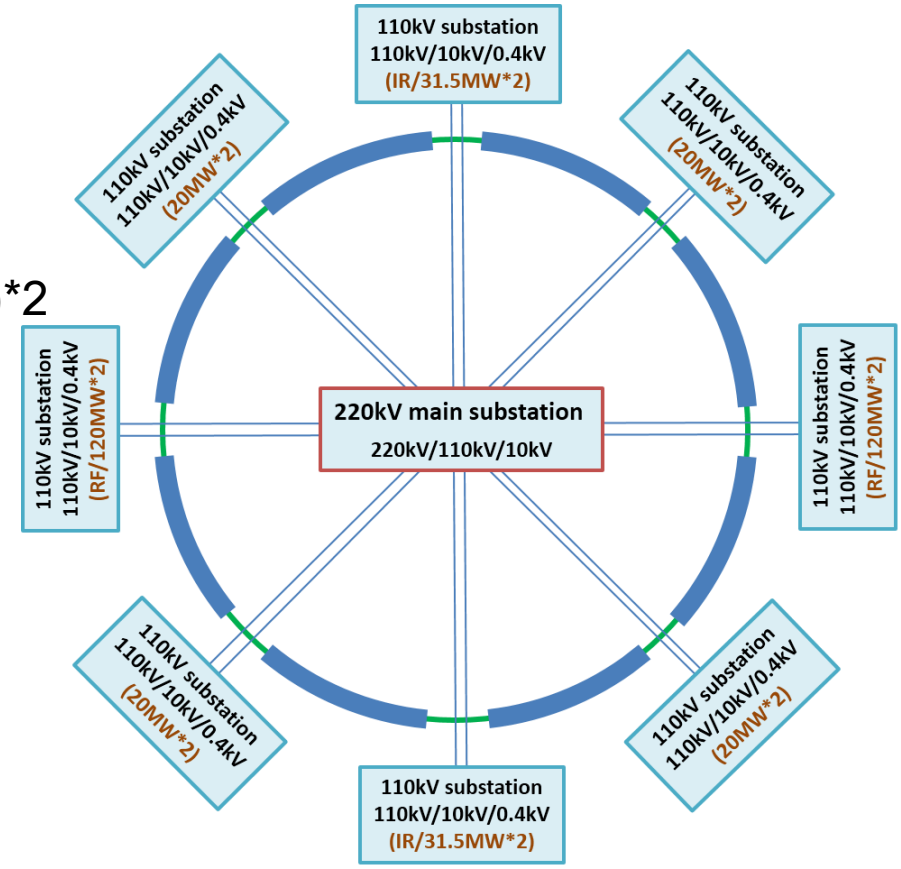
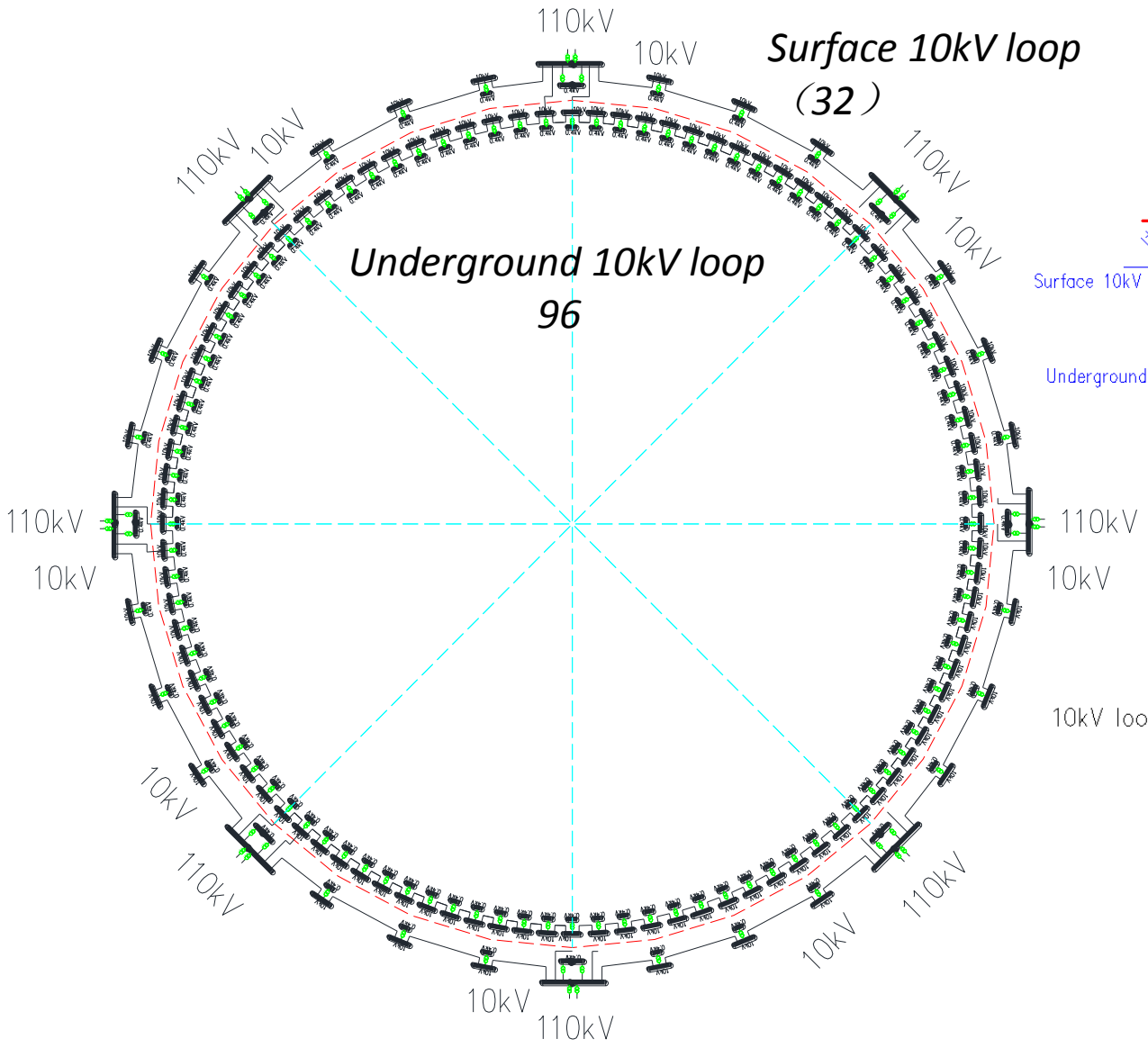


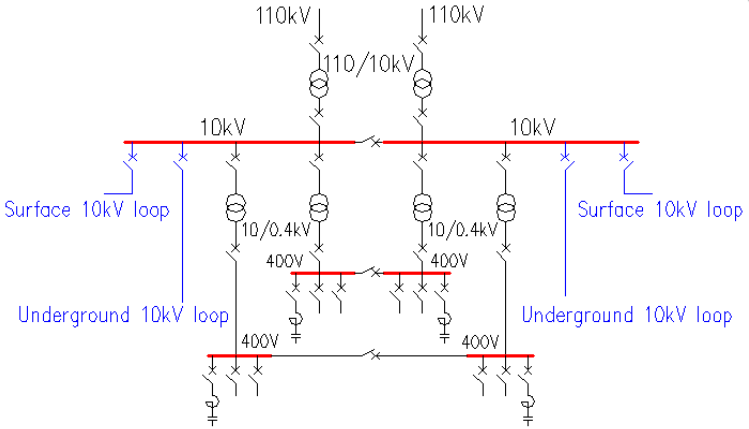
Diagram of 110kV distribution system

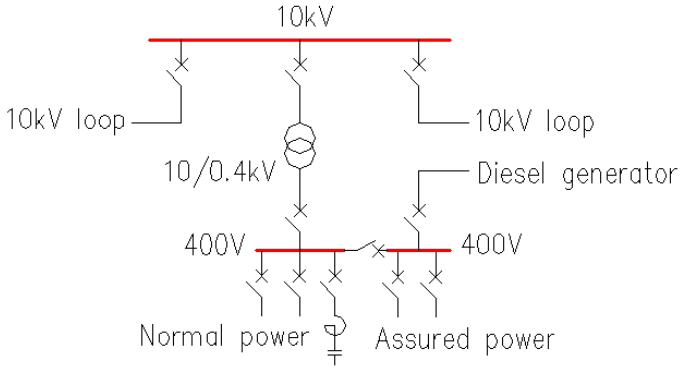
Electricity distribution system（cont'd）

- 10kV step-down substations
  - Surface 10kV loop
    - Several substations (10/0.4kV) at each surface area of ring
      - 10kV feeders from 110kV substation nearby
      - Rated capacity of transformer: 4~12*2000kVA (10/0.4kV)
    - 1 substation (10/0.4kV) at LINAC
      - Rated capacity of transformer: 6*2000kVA (10/0.4kV)
  - Underground 10kV loop
    - 96 substations (10/0.4kV) along the ring tunnel
      - Rated capacity of transformer: 1*630kVA (10/0.4kV)
- Back up diesel generator sets maybe required for personnel safety: lifts, smoke extraction etc.
- Instrumentation and power converter control systems may require uninterrupted power supplies (UPS)

Schematic diagram of 10kV electric power network







Cooling water system

- The heat load dissipated by CEPC machine:

System	Location and heat loads(MW)					
	Ring	Booster	LINAC	BTL	IR	Total
RF power source	100	5	1.2			106.2
Magnets	51.5	5.54	1.35	1		59.39
Converters for magnets	9	0.8	0.11	0.1		10.01
Cryogenics	16	2			2	20
Experimental devices					10	10
Vacuum chamber（SR）	58					58
condenser in stub tunnel	8					8
Pump	6.5	1.5	0.35	0.1	0.36	8.81
Total	249	14.84	3.01	1.2	12.36	**280.4**

Cooling water system（cont'd）

- Key requirements and parameters

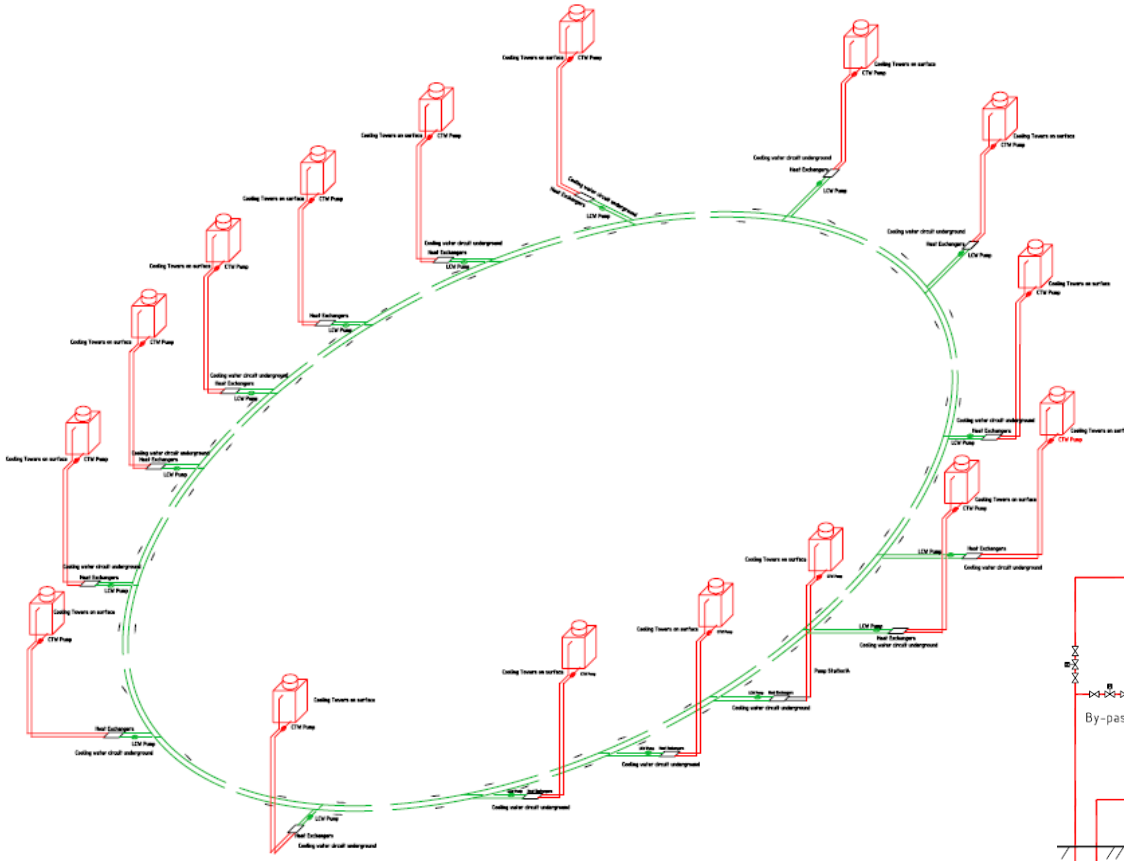
Design parameter	Unit	quantity
Total heat load	MW	280
Total low-conductivity water (LCW) flow rate	t/hr	30000
Total cooling tower water (CTW) flow rate	t/hr	52000
Total capacity of cooling towers	MW	300

  - Cooling water temperature
    - Cooling tower water temperature: ＜ 29℃
      - Based on wet-bulb air temperature of 26℃ ambient
      - Machine is shut down in summer
    - LCW cooling water temperature: ＜ 32 ℃

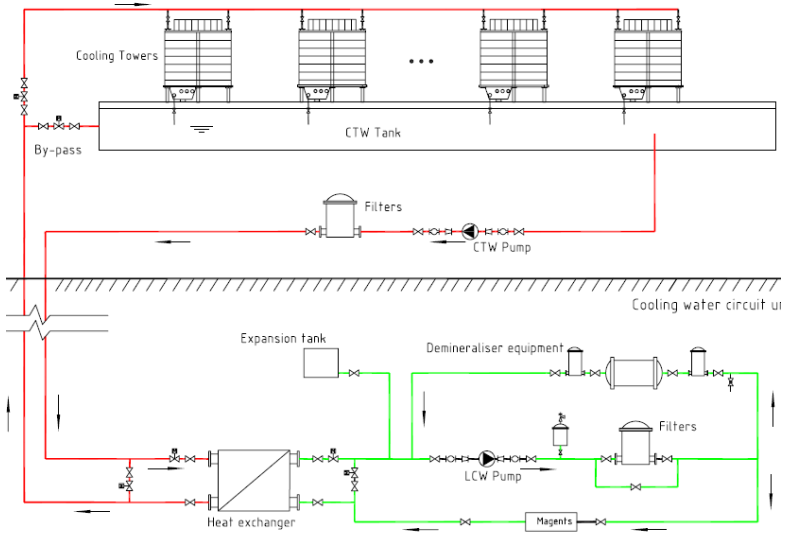
Cooling water system（cont'd）

- Layout of cooling water system
  - There are several on-site closed-loop cooling water circuits(LCW) in LINAC, ring, experimental hall respectively
    - LINAC
      - klystron cooling circuits
      - Accelerator tube, waveguide etc. cooling circuits
    - Ring / booster
      - Magnet cooling circuits at P1-8 and C1-8 (16 circuits)
      - vacuum chamber cooling circuits at P1-8 and C1-8 (16 circuits)
      - Power converters cooling circuits at P1-8 (8)
      - RF power source cooling circuits at P3 and P7 (2)
      - Helium compressor (CTW) circuits at P3 and P7 (2)
    - BTL cooling circuit
    - Dedicated cooling water system for experimental device
  - Deionized water device at P1-8, C1-8 and LINAC (17)
    - Supply low-conductivity water for makeup
  - Cooling tower water pump station at P1-8, C1-8 and LINAC (17)
    - As coolant for on-site cooling system

Schematic layout of cooling circuits in the tunnel



- *There are 16 circuits for magnets and vacuum pipe around tunnel respectively.*
- *Primary loops(CTW) on surface*
- *Secondary loops (LCW) are underground.*



Flow diagram of typical cooling water circuits

HVAC

- Estimated cooling loads of HVAC
  - Ring tunnel

System	Location and cooling loads(MW)		Total （MW）
	Ring	Booster	
Magnets	2	1	3
Cable in tunnel	32.5	3.5	36
General and dedicated services	6	2	8
Synchrotron radiation	2	1	3
Total	42.5	7.5	**50**

  - Service buildings: (200W/m^2) 28MW
  - Total cooling load: 80MW

HVAC（cont'd）

- Indoor air design conditions
  - Ring tunnel
    - Air temperature
      - Inlet:18-20℃
      - Outlet: less than 35 ℃
    - Relative humidity: 50% ~ 60%, and shall be lower than 65%
  - Experimental halls
    - Temperature: about 26℃(summer), 20℃(winter),
    - relative humidity is 50% ~ 60%, and shall be lower than 65%
  - Control room (or electronics)
    - Temperature: about 20-25℃
    - relative humidity: about 45-60%
  - Other service building
    - Temperature: about 28℃(summer), 18℃(winter),
    - relative humidity: lower than 65%

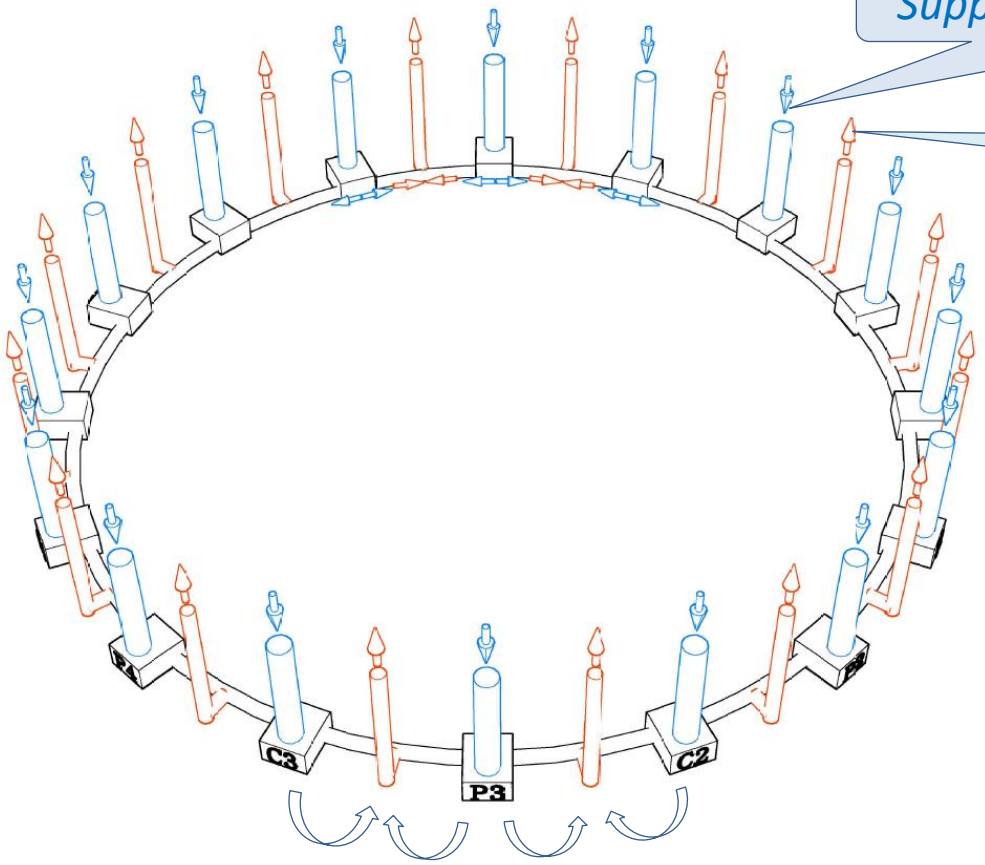
HVAC（cont'd）

- Coolant for air conditioning: chilled water

Design parameter	Unit	quantity
Total cooling load	MW	80
Total chilled water flow rate	t/hr	14000
Total cooling tower water flow rate	t/hr	18000
Total capacity of cooling towers	MW	100

- Heat source for heating system in winter
  - Heat pump (heat recover from cooling system)
  - Backup boiler

Schematic air flows in the tunnel



Supply air by AHU at P1-8, C1-8

Exhaust air adjacently at V1-16

Tunnel air flow rate: 80000 m^3/hr
The velocity is 1.0m/s

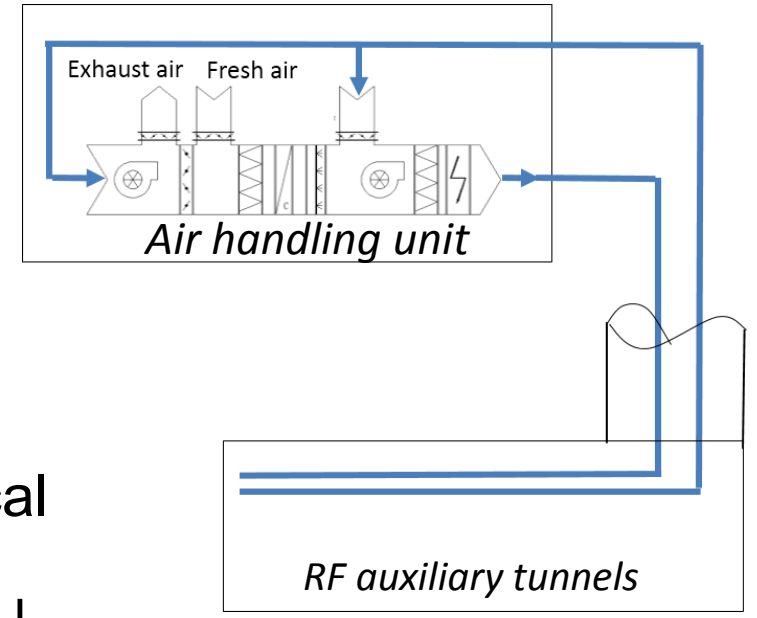
- The tunnel is divided into 32 independent sections
- To supply air by AHU at P1-8 and C1-8 (16 points)
- To exhaust air *adjacently* at V1-16, filtered by HEPA (16 points)

Operation scenario

- machine operation mode
  - Temperature and humidity in tunnel are maintained by inlet air
- Transitional mode
  - To purge air in the tunnel before access
- Accessible mode
  - The air flow rate could be cut down
- Emergency mode
  - In case of smoke and gas extraction

HVAC（cont'd）

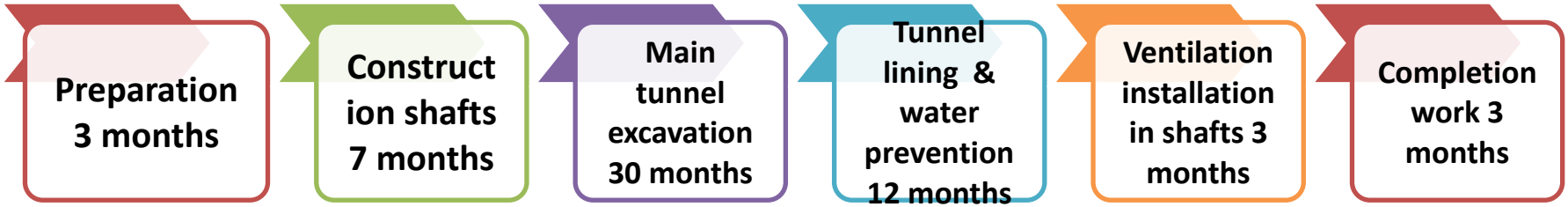
- RF auxiliary tunnels and experiment hall
  - Air conditioned and ventilated by mechanical supply and extraction of air via ducts in access shaft
  - AHU is on ground level.
  - Dedicated smoke, gas extraction systems
- Auxiliary stub tunnels
  - Air conditioned and ventilated by local AHU
    - Because there is no chilled water, AHU contains a refrigerator unit which is cooled by deionized water from magnet circuits
- Other service buildings
  - AHU
  - or fan-coil + fresh air system



Civil construction Schedule

The total construction period is 58 months, including preparatory work of 10 months, main works of 45 months and completion work of 3 months.

The critical activities are :



The surface buildings and electrical installation are carried out in parallel and not on the main path.

Summary

- Several optional sites have been investigated. The favorable site is Funing County.
- The key requirements for buildings will be optimized and defined soon.
- The technical requirements for utilities have been studied and will be optimized in the next step.
- Detailed study and further efforts on cut-down of electrical power consumption are necessary in the future.

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Thank you for your attention

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