Lecture 11 (9 October 14:30-16:00)

Conventional Facilities

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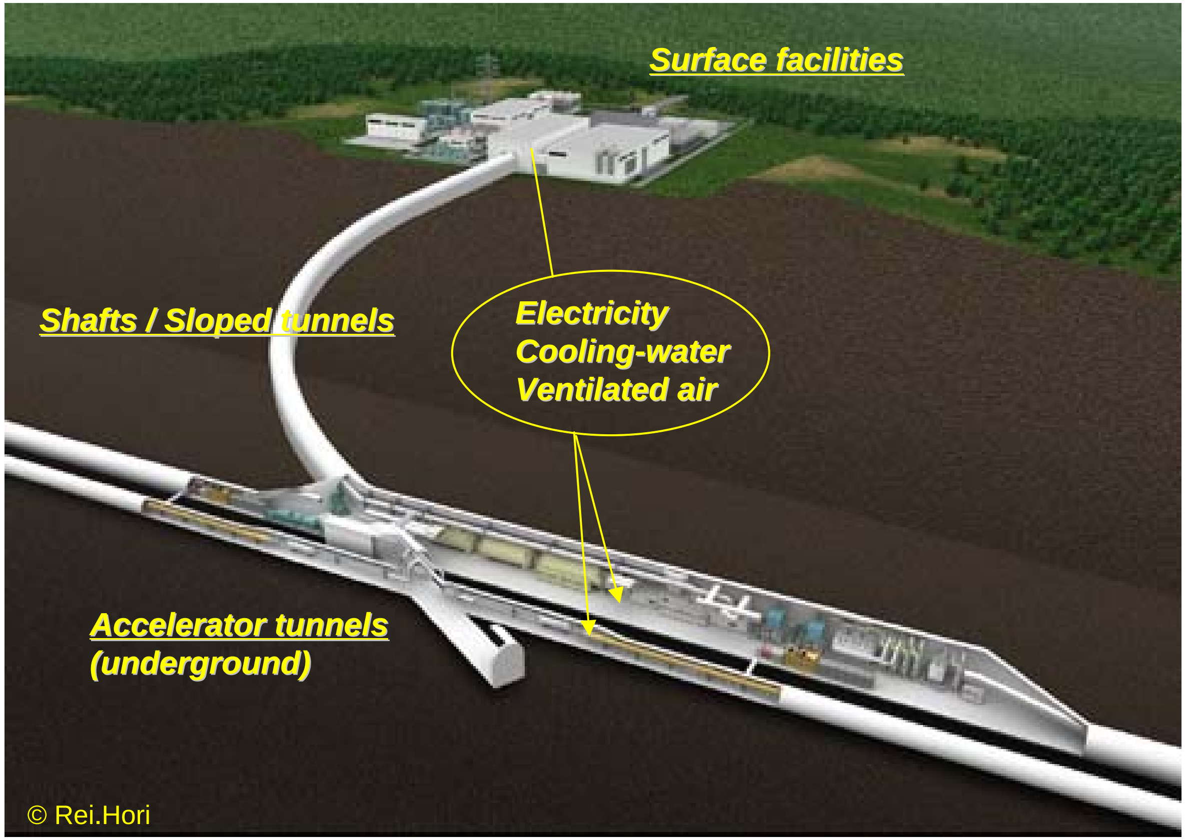
Contents

- Overview (20min)
- Tunneling (20min)
- Site requirement (20min)
- LHC Construction (20min)

Overview

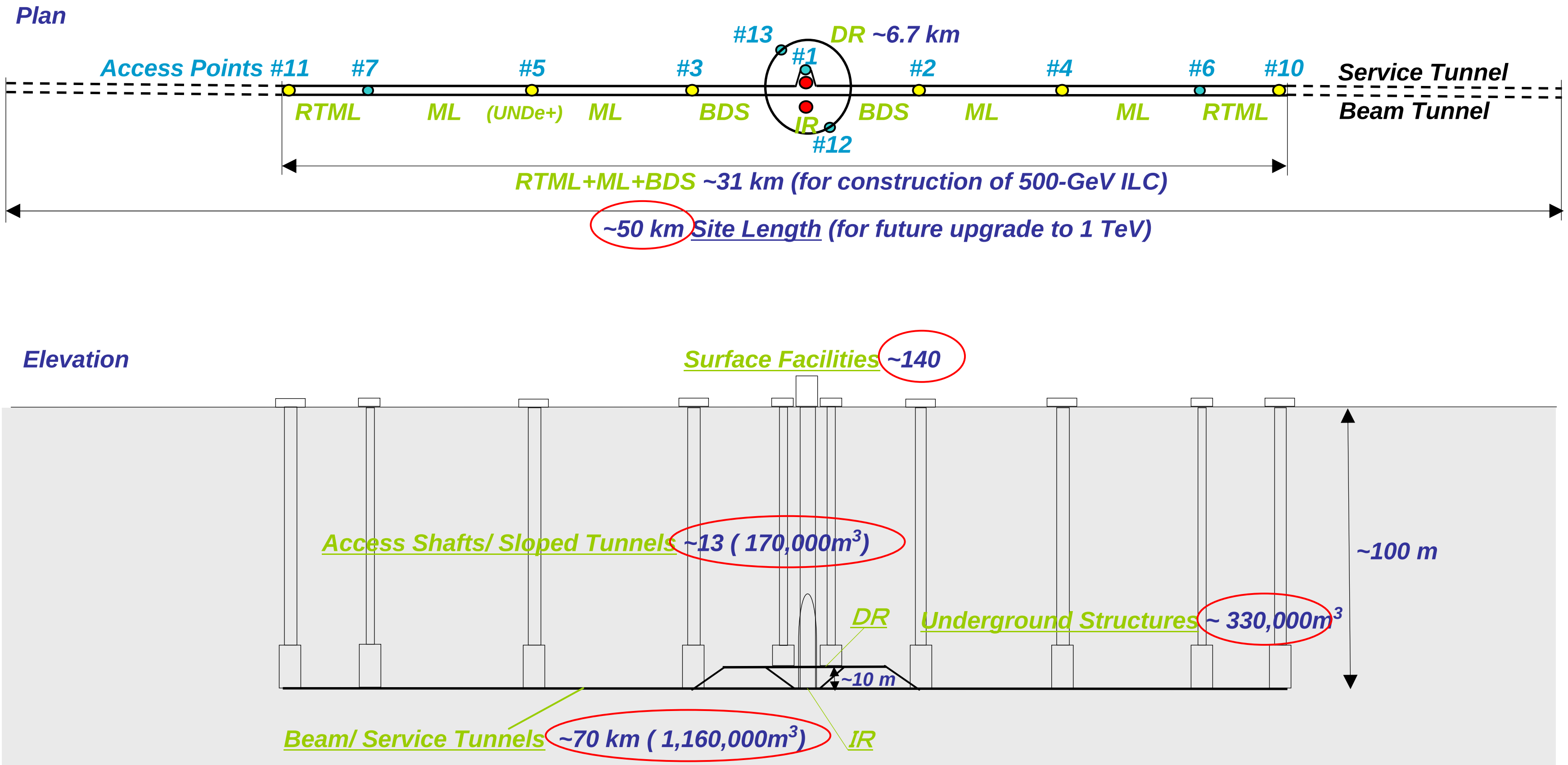
What is Conventional Facility (CF)?

- Conventional facility is composed of
  - underground accelerator tunnels accessed from surface facilities with shafts
  - and equipment which provides accelerators with electricity, cooling-water, and ventilated air.



What is required for CF?

- *Civil Engineering*
  - *Surface, Access, Underground*

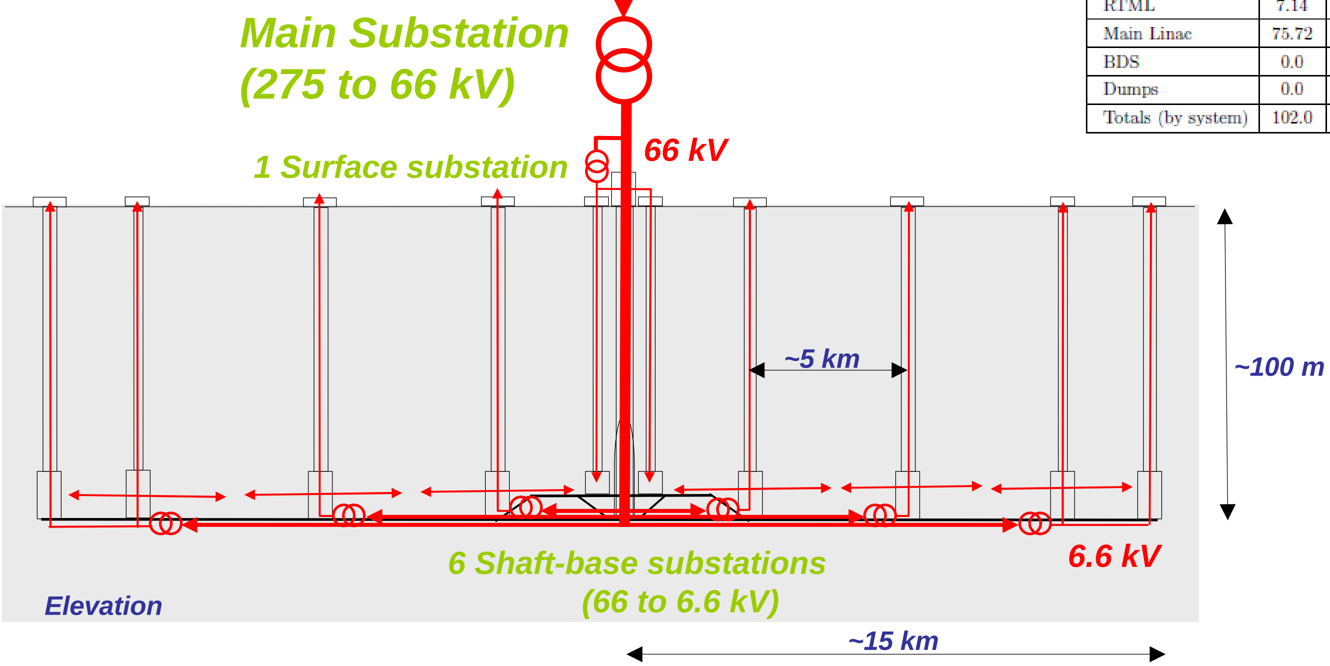


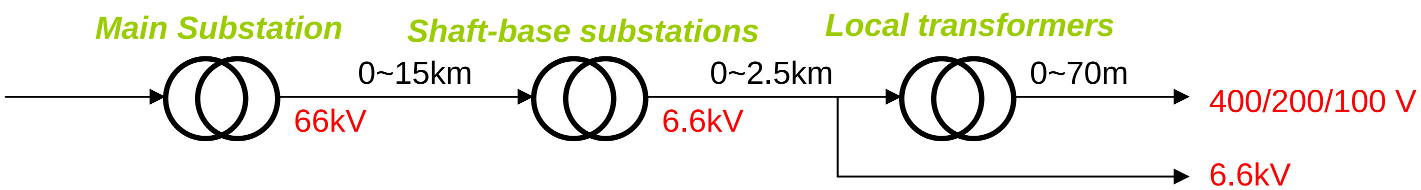
What is required for CF?

- **Electricity** 275 kV (~220 MW)

Estimated nominal power loads (MW) for 500 GeV centre-of-mass operation

Area System	RF Power	Conventional Power				Emer Power	Total (by area)
		Conv	NC Magnets	Water Systems	Cryo		
Sources e^-	1.05	1.19	0.73	1.27	0.46	0.06	4.76
Sources e^+	4.11	7.32	8.90	1.27	0.46	0.21	22.27
DR	14.0	1.71	7.92	0.66	1.76	0.23	26.29
RTML	7.14	3.78	4.74	1.34	0.0	0.15	17.14
Main Linac	75.72	13.54	0.78	9.86	33.0	0.4	134.21
BDS	0.0	1.11	2.57	3.51	0.33	0.20	7.72
Dumps	0.0	3.83	0.0	0.0	0.0	0.12	3.95
Totals (by system)	102.0	32.5	25.6	17.9	36.9	1.4	216.3



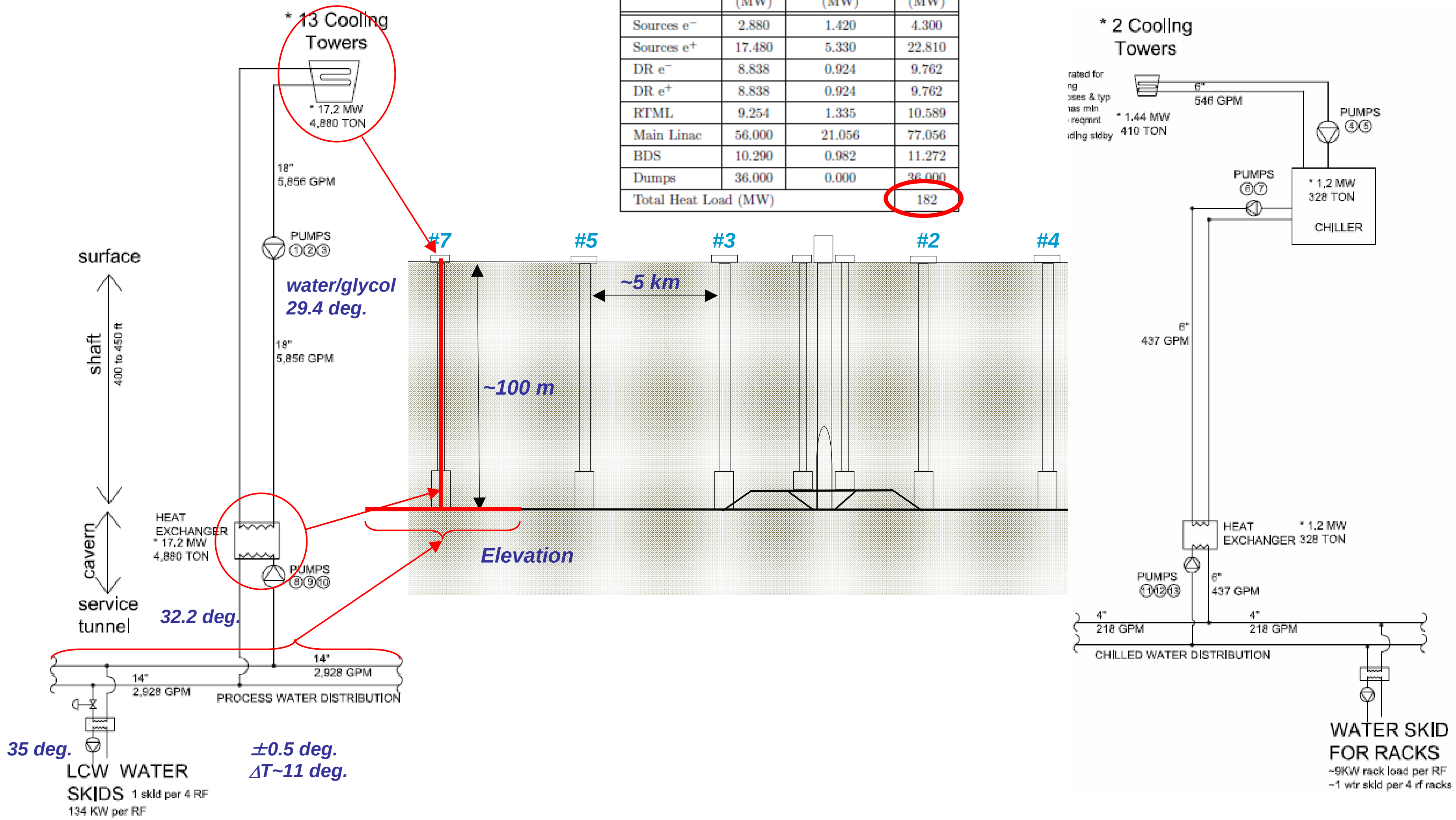


What is required for CF?

- **Cooling-Water**

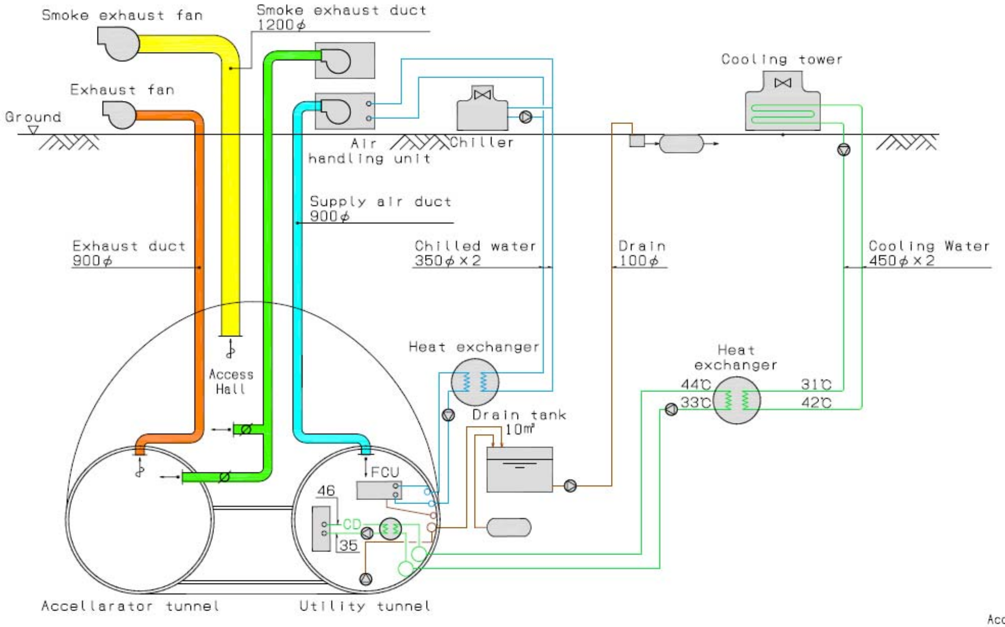
Summary of heat loads broken down by Area System

Area System	LCW (MW)	Chilled Water (MW)	Total (MW)
Sources e⁻	2.880	1.420	4.300
Sources e⁺	17.480	5.330	22.810
DR e⁻	8.838	0.924	9.762
DR e⁺	8.838	0.924	9.762
RTML	9.254	1.335	10.589
Main Linac	56.000	21.056	77.056
BDS	10.290	0.982	11.272
Dumps	36.000	0.000	36.000
Total Heat Load (MW)			182



What is required for CF?

- **Ventilated Air**

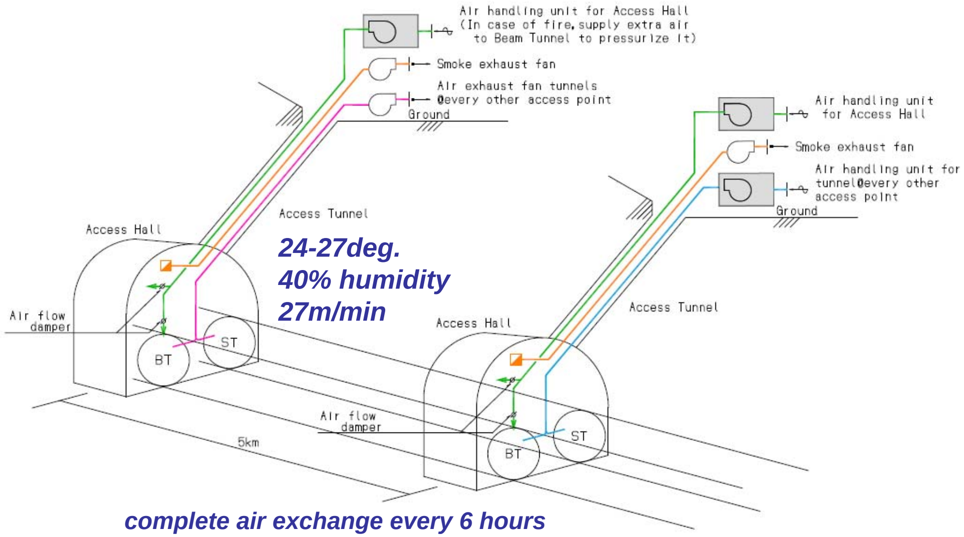


Schematic diagram of HVAC system

HVAC requirements

Location	Temperature (drybulb)	Dewpoint	RH	Air Flow
e- Source	29°C	<13°C	<35%	27 m/min
Damping Ring	40°C	<13°C	<20%	27 m/min
Main accelerator service tunnel	29°C	<13°C	<35%	27 m/min
Main Linac beam tunnel (not contr.)	>30°C	<13°C	<35%	27 m/min
BDS beam tunnel	29-32°C	<13°C	<35%	27 m/min
IR hall	29-32°C	<13°C	<35%	27 m/min

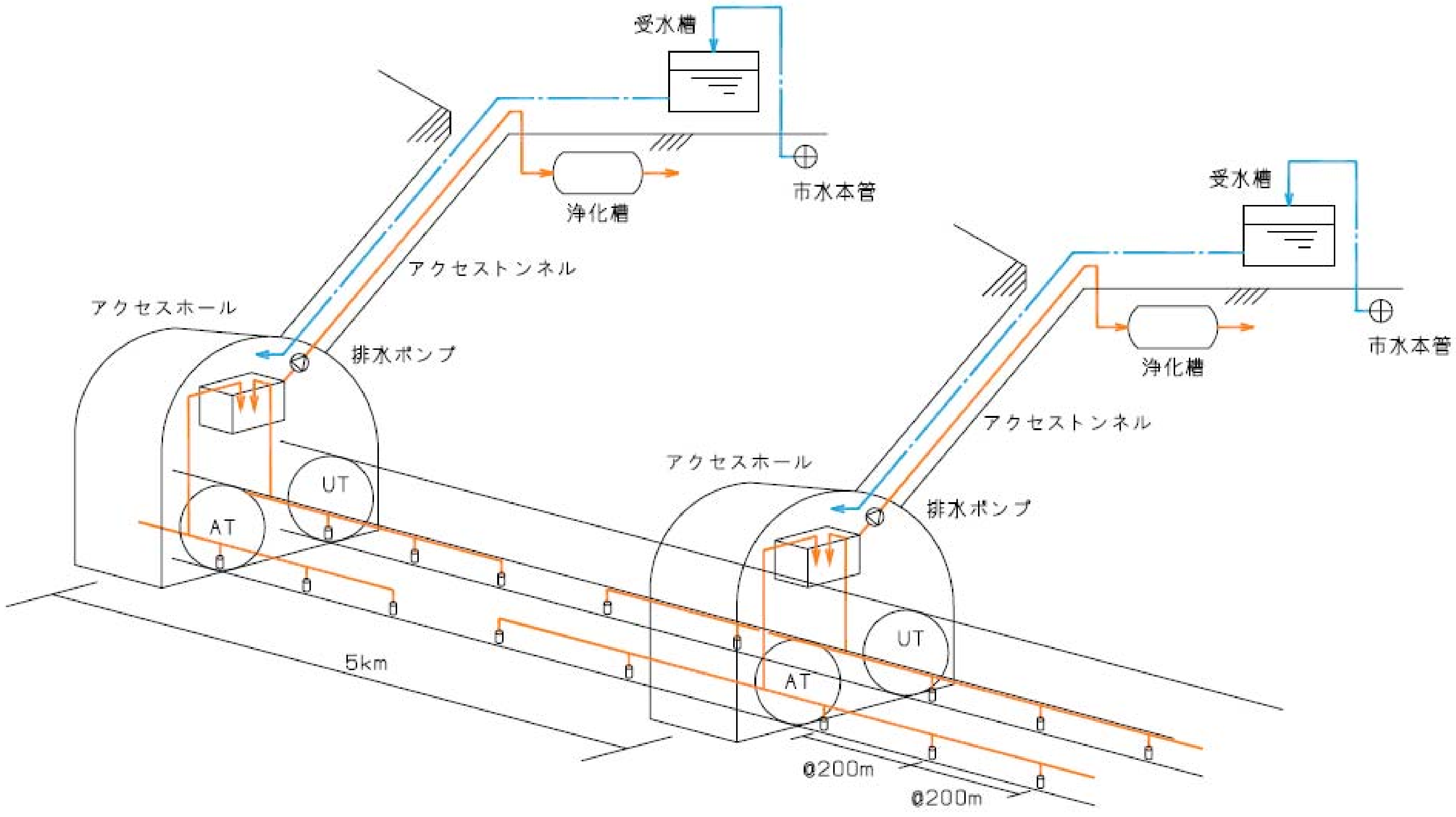
68,000 m3/hr
15% (10,200 m3/hr) vented



HVAC & SMOKE EXHAUST SYSTEM

What is required for CF?

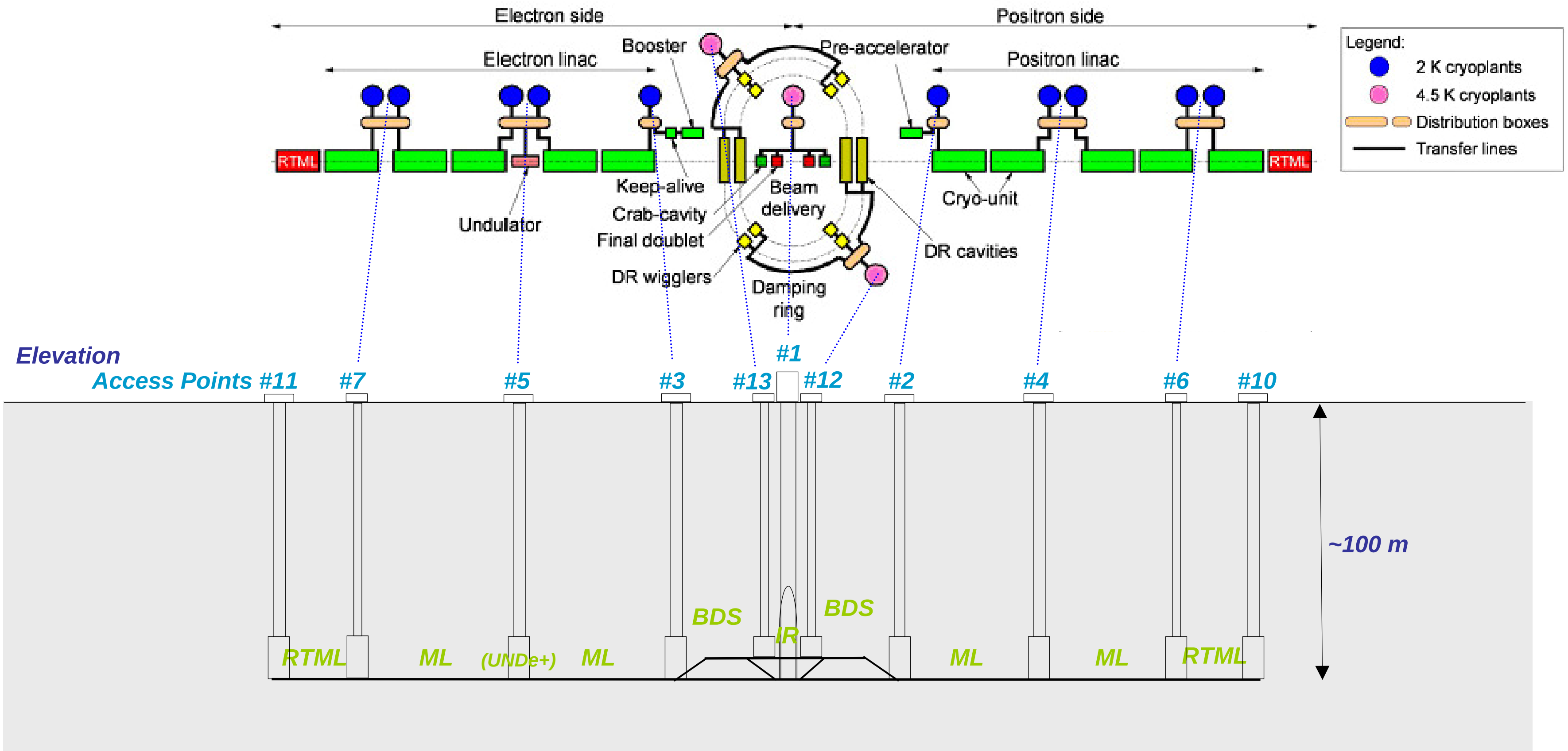
- *Potable water and drainage system*



トンネル給排水概念図

What is required for CF?

- *Cryogenic system*

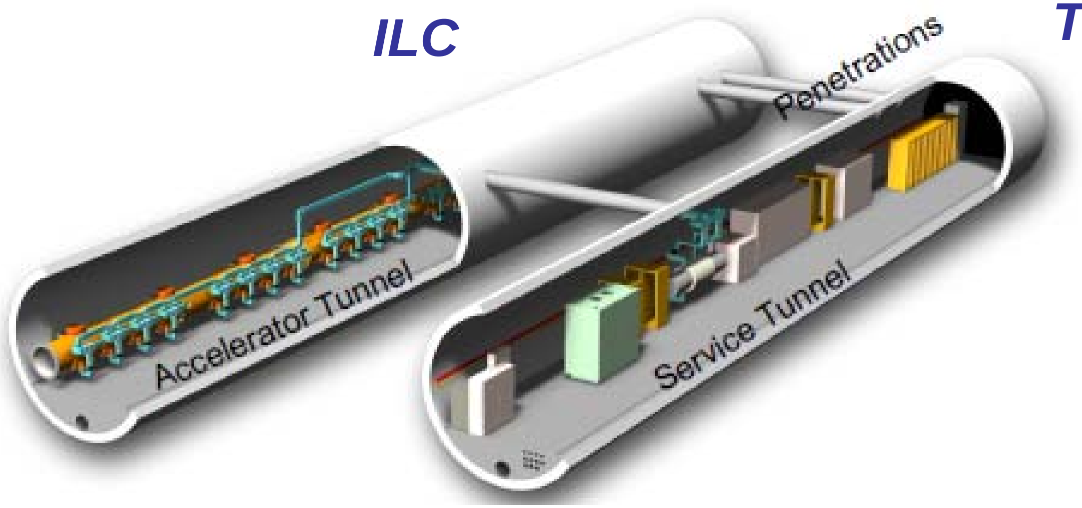


Tunneling

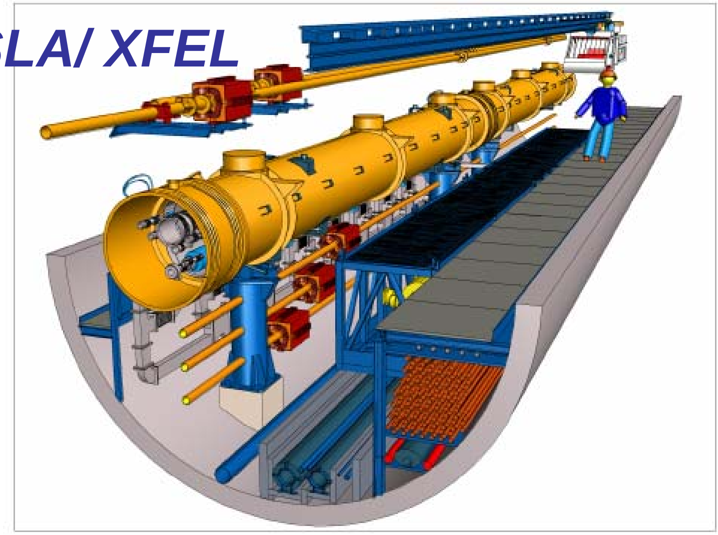
How are the Accelerator Tunnels designed?

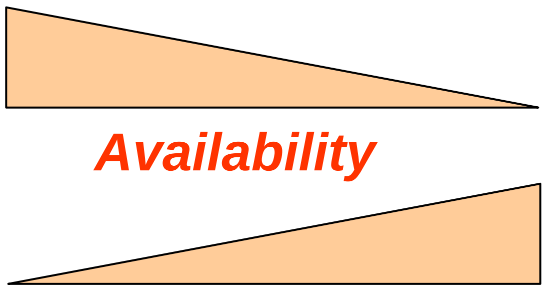
- *1-tunnel scheme vs 2-tunnel scheme*

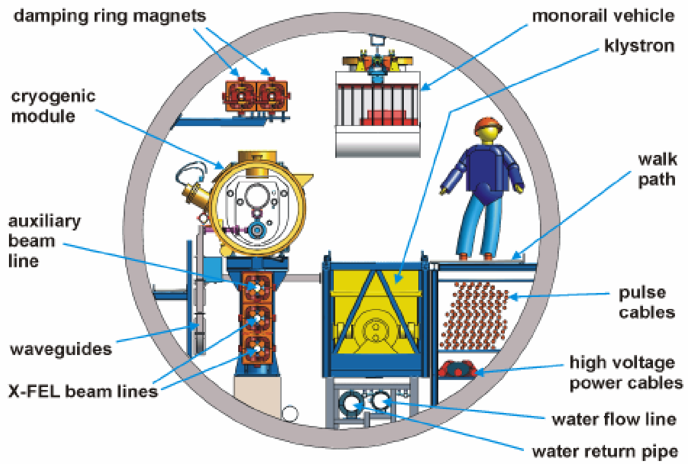
ILC



TESLA/ XFEL

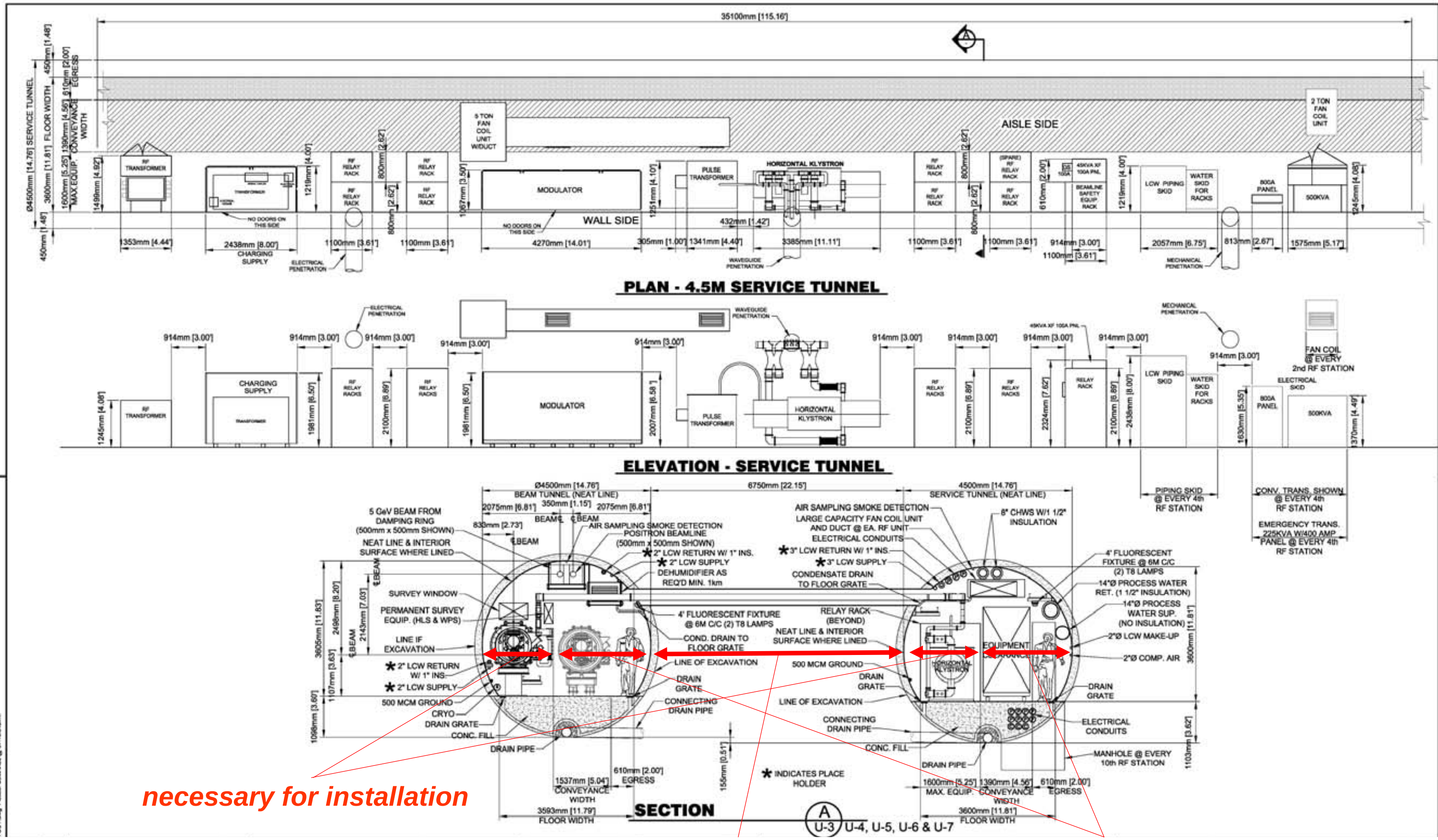






(From TESLA Design Report)

Main Linac Tunnel



necessary for installation

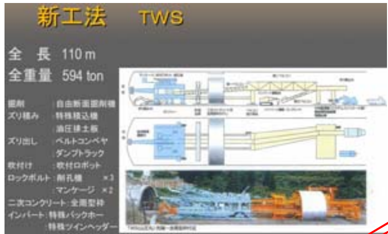
- *How were the dimensions determined?*
  - *Length, diameter, distance between tunnels,*
- *How are the accelerator components located?*
  - *Cryomodule, klystron,*
    - *Sub-sub-subtitle*

~1.5 x tunnel diameter, necessary for excavation, enough for radiation shield

necessary for maintenance, emergency egress

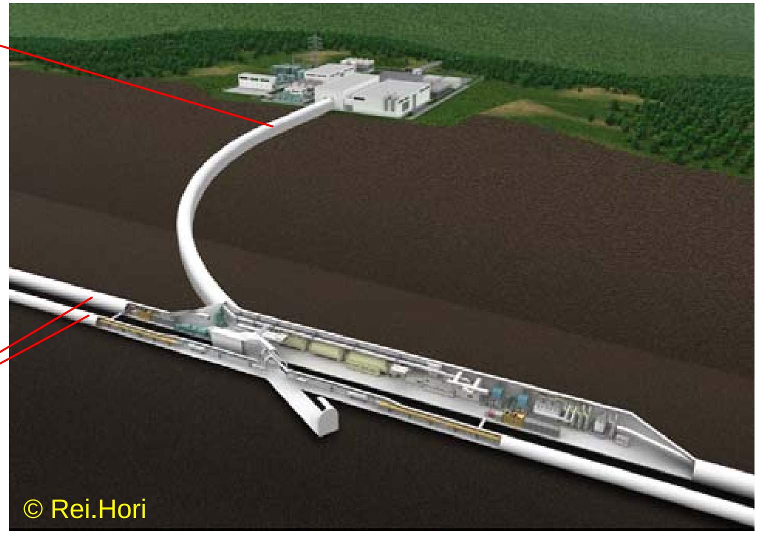
How to excavate tunnel

- **Drill with/without Blast**
  - ⇨ **short tunnel**
  - – Low speed (~5m/day), lower cost, noisy



From materials of Japan Construction Mechanization Association (JCMA).

- **Tunnel Boring Machine (TBM)**
  - ⇨ **long tunnel**
  - – High speed (10~30 m/day), expensive machine with long delivery period



Kawasaki Heavy Industries, Ltd.

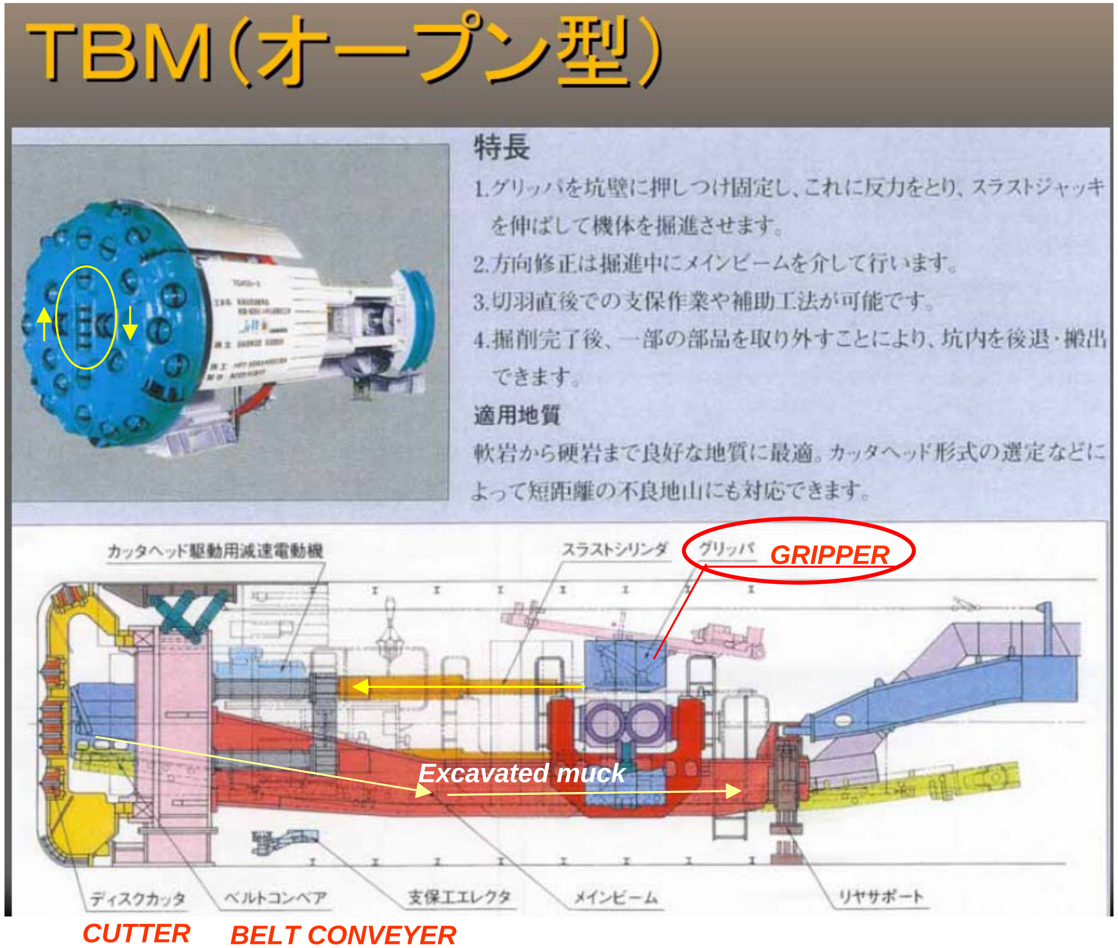
One of the world's largest tunnel boring machines. It has a diameter of more than 14 m.

A Eurostar high speed passenger train leaving the EuroTunnel.

The oldest train tunnel was constructed between Riverpool and Manchester in 1826. The Euro Tunnel is 52km long including two 7.6m diameter main tunnels and one 4.8m tunnel for service. Four Japanese TBMs of the total eleven TBMs excavated the main tunnels 20km each from the French side. The maximum excavation speed reached 1200m/month.

Tunnel Boring Machine (TBM)

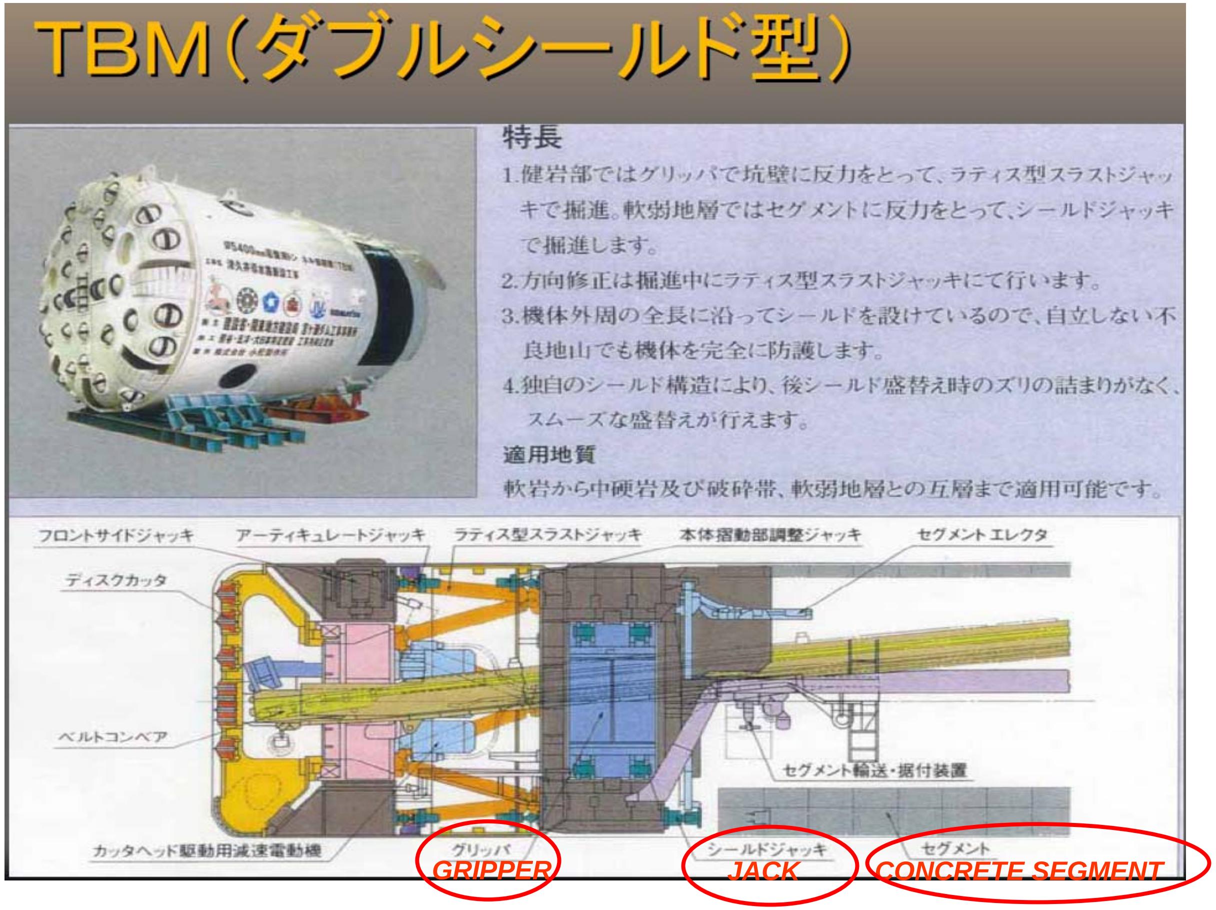
- **Open type (firm bedrock)**
  - *High speed, anchored to side wall by "GRIPPER"*



From materials of Japan Construction Mechanization Association (JCMA).

Tunnel Boring Machine (TBM)

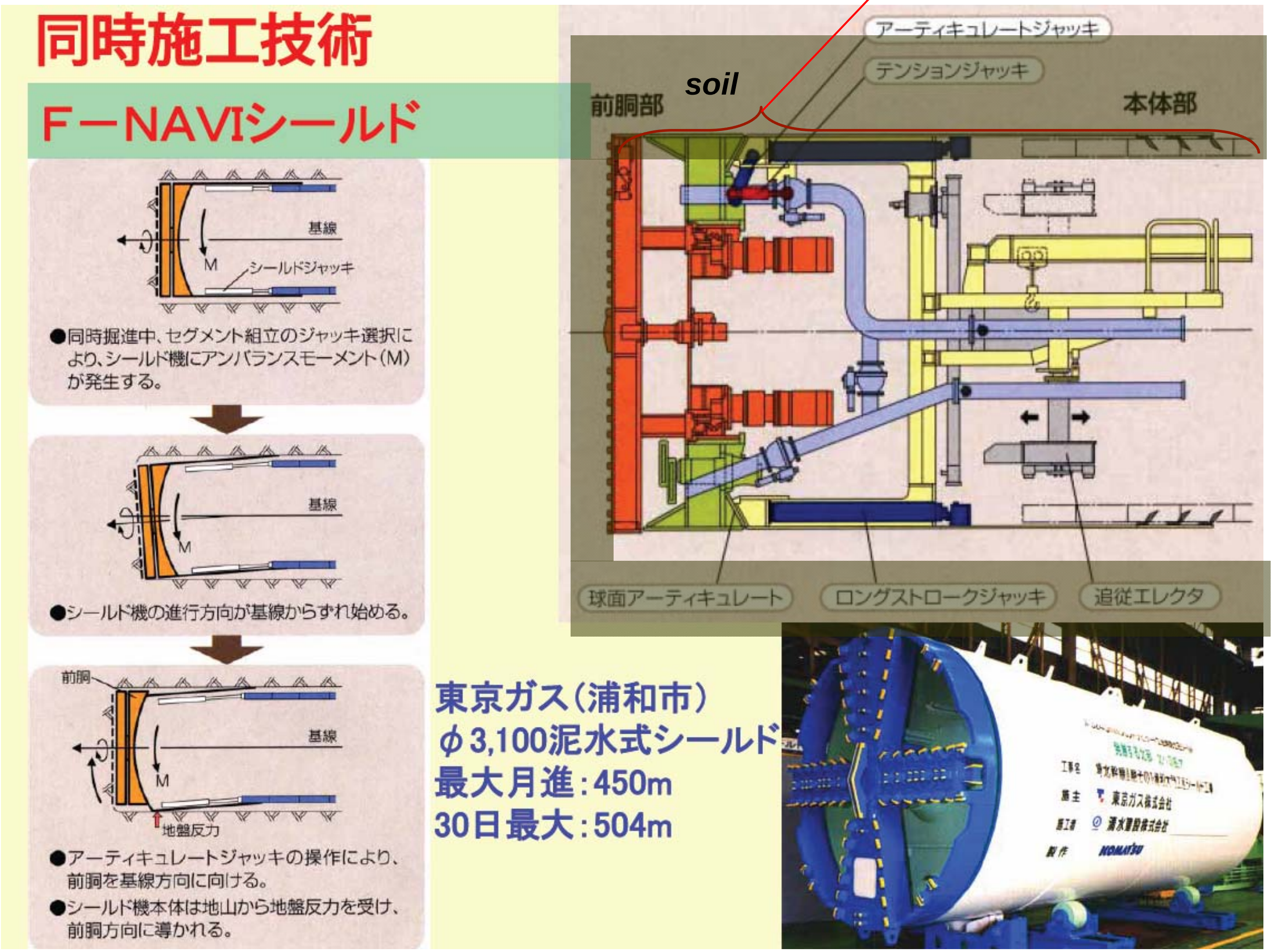
- ***Shield type (firm and soft mixed geology)***
  - *Anchored to side wall by “GRIPPER” or to concrete segment by “JACK”*



From materials of Japan Construction Mechanization Association (JCMA).

Tunnel Boring Machine

- ***"Shield Machine" (soft soil)***
  - *High speed, anchored to concrete segment, totally shielded against soft soil*

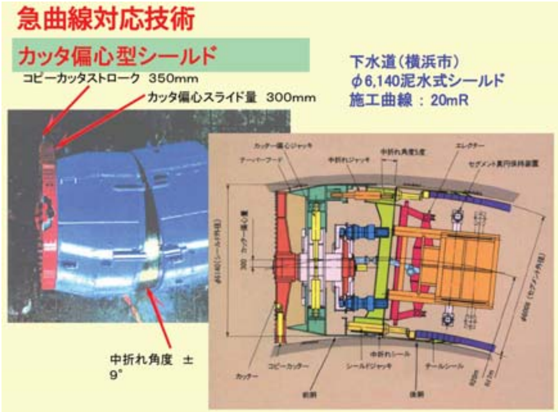


From materials of Japan Construction Mechanization Association (JCMA).

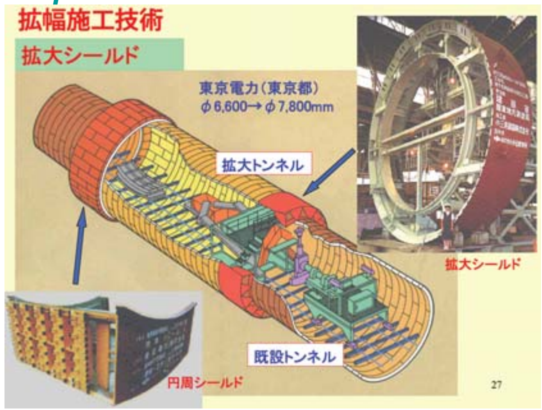
Tunnel Boring Machine (TBM)

- ***Variation (soft soil)***

Sharply-curved Tunnel

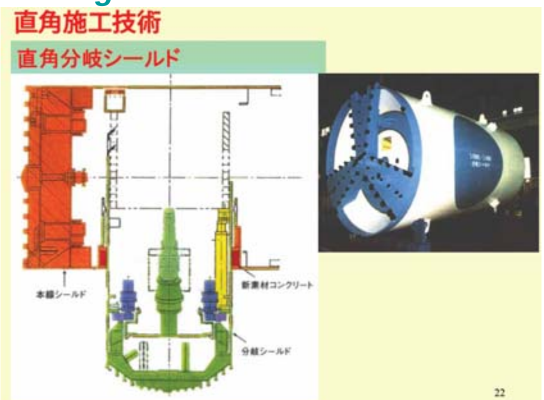


Expansion



Overlapped Double Tunnel

90-degree Branch

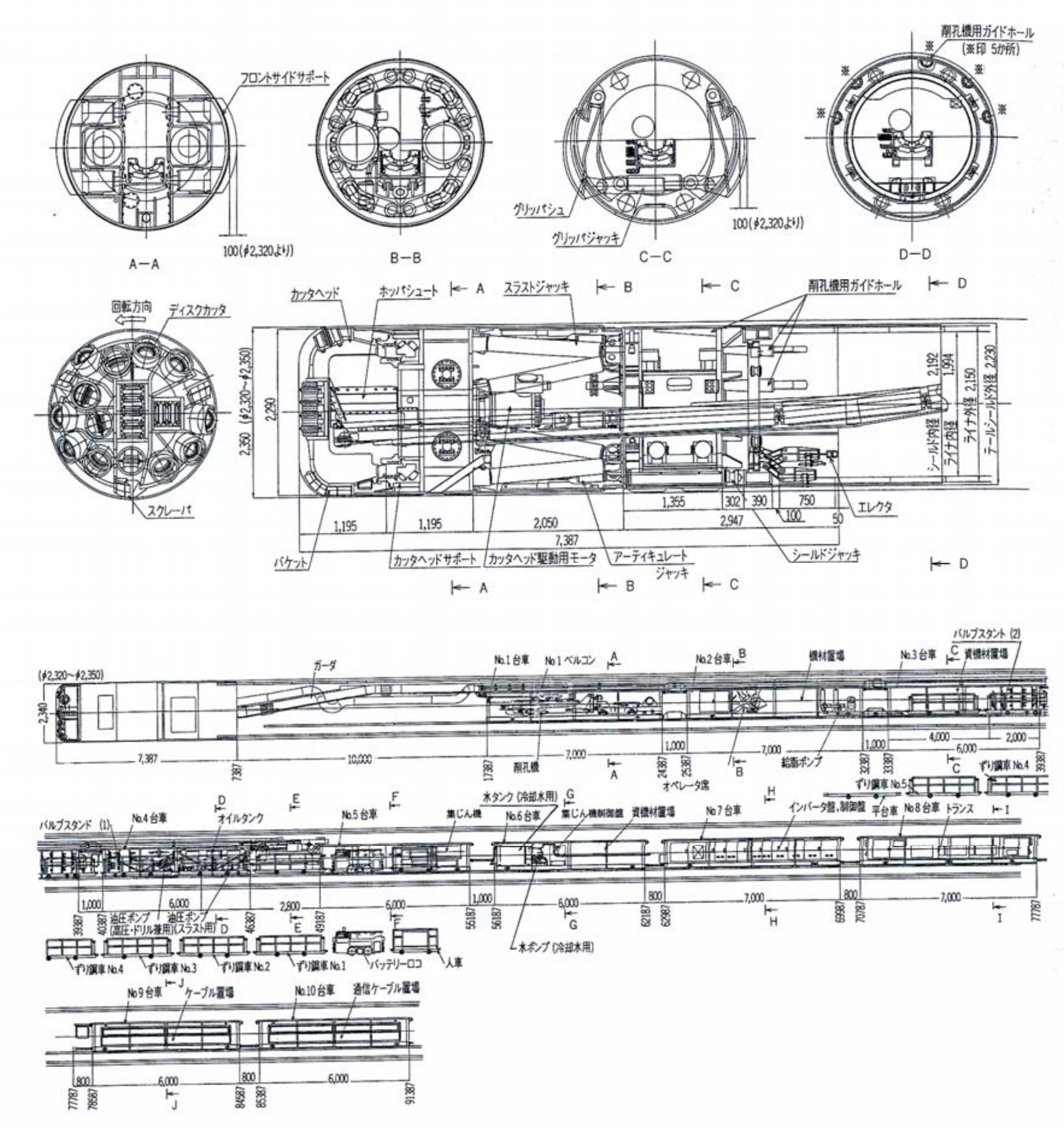


Tunnel with Non-circular Profile

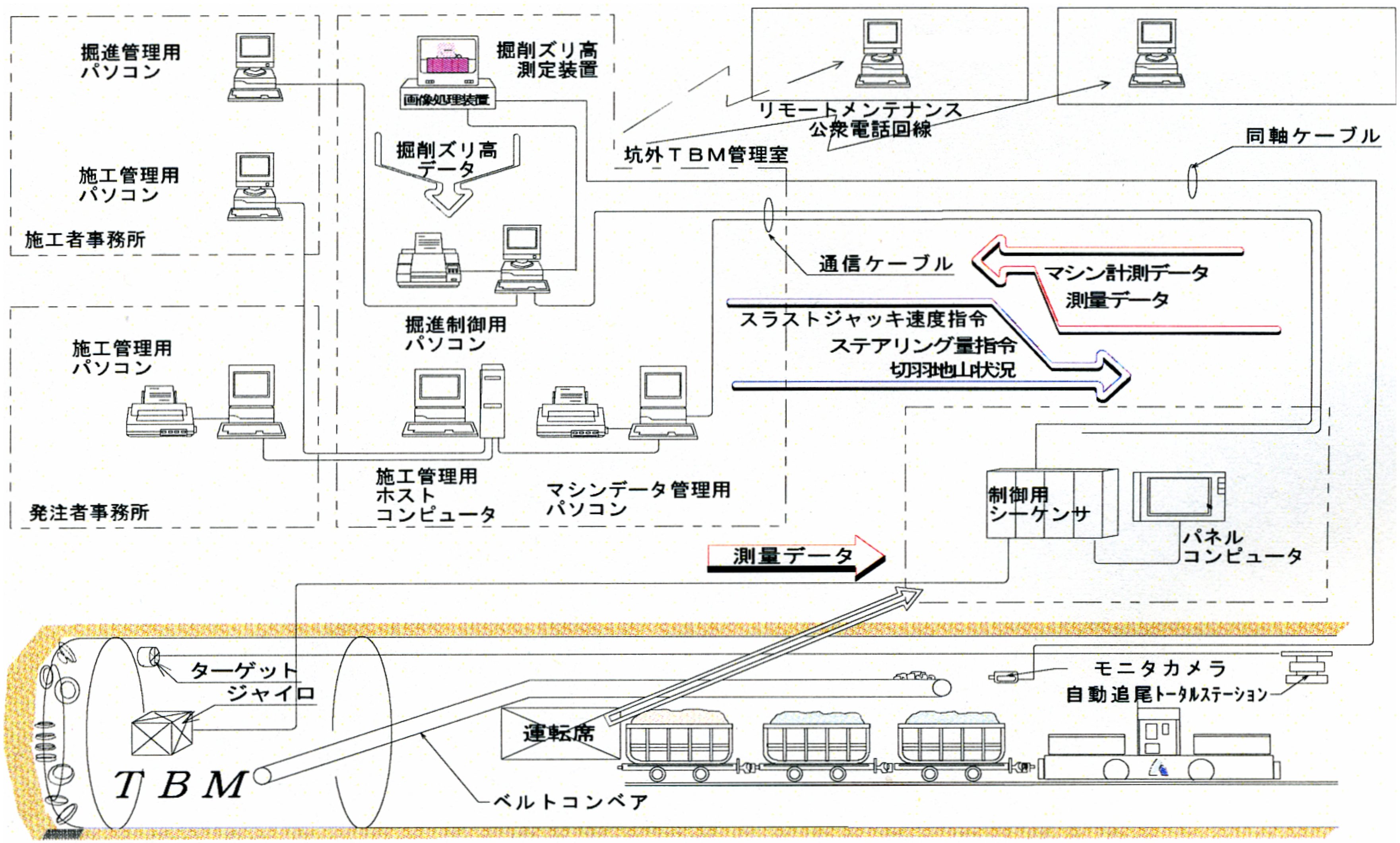
From materials of Japan Construction Mechanization Association (JCMA).

TBM Train

- ***TBM is a long train (~100m) composed of a cutter head and following cars.***
- ***Before TBMs start to excavate tunnels, they are lifted down from access points into the underground hall and assembled.***
- ***One TBM excavates 5 to 10 km according to a given construction schedule.***



Automatic Operation of TBM Train



TBM Construction Speed (1)

- ***Average construction speed with TBM has been improved.***

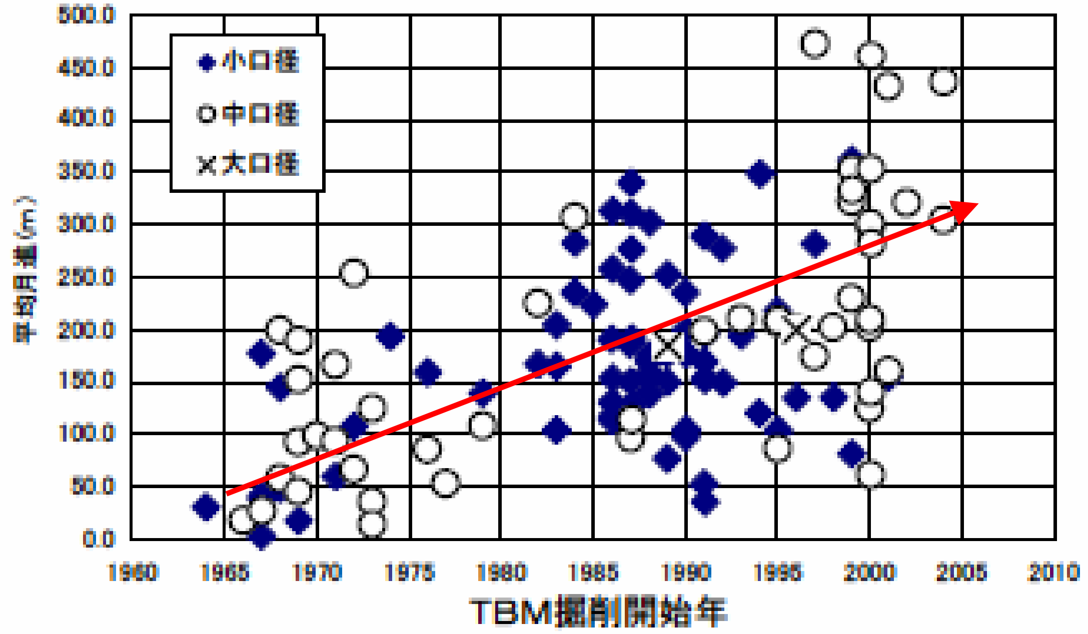


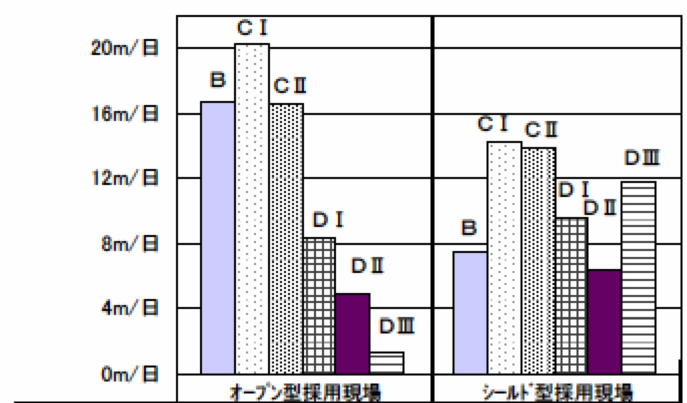
図3. 2. 6　掘削開始年別平均月進（径別）

(From “Current Status of TBM and Rapid Excavation Technology”, Japanese Association of tunneling Technology, Sep. 2006)

- ***(Definition) Tunnel length /overall construction days x 30.***
- ***The monthly construction speed in Japan is 252 m averaging 48 tunnels longer than 2000 m constructed using TBM since 1986.***
- *Excavation speed recently became increasing* ***by improving TBM, peripheral technology, and operation performance,*** *reaching 473 m at maximum****.***

TBM Construction Speed (2)

- ***Construction speed depends on the geology and quality of bedrock at which ILC is constructed.***



地山区分別日進(m/日)		オープン型採用現場	シールド型採用現場
	B	16.8	7.5
	C I	20.3	14.2
	C II	16.6	13.9
	D I	8.3	9.6
	D II	4.9	6.3
	D III	1.4	11.8

図2. 2. 5　ＴＢＭ型式別地山区分毎の平均日進

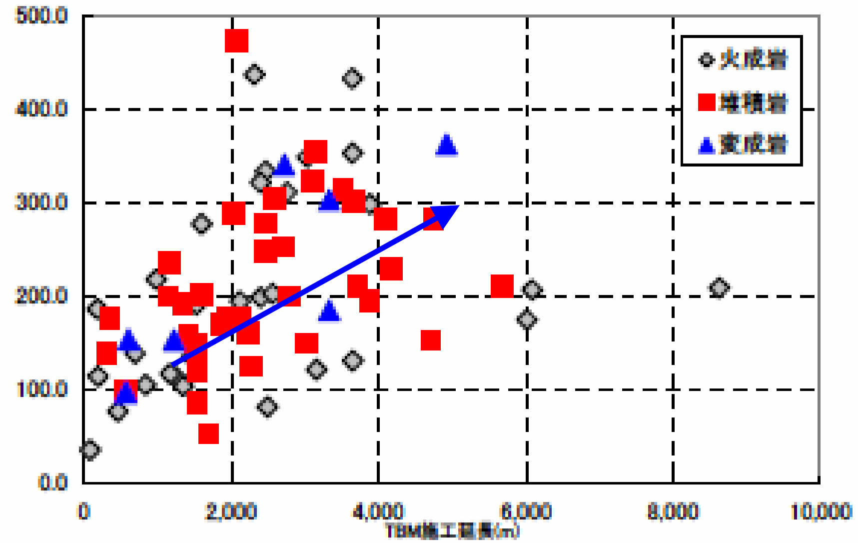


図3. 2. 7　施工延長別の平均月進（岩種別）

(From “Current Status of TBM and Rapid Excavation Technology”, Japanese Association of tunneling Technology, Sep. 2006)

- ***Construction day includes TBM operation, supplementary works, and break days. Net TBM operation days are around 55%.***
- *The construction speed depends* ***not on the type of rocks such as igneous rock and sedimentary rock, but*** *on the condition of bedrock.*
- *Tunnel construction speed seems to increase as the tunnel length increases up to 4000m.*

TBM Performance in the world

- *Among 654 tunnels constructed by TBM since 1986, Japan did 111, USA, 106, Switzerland 81, Italy 30, Germany 11, …*
- *Small (<3.5m) size are dominant in Japan, middle (3.5-7m) size in the US and EU.*

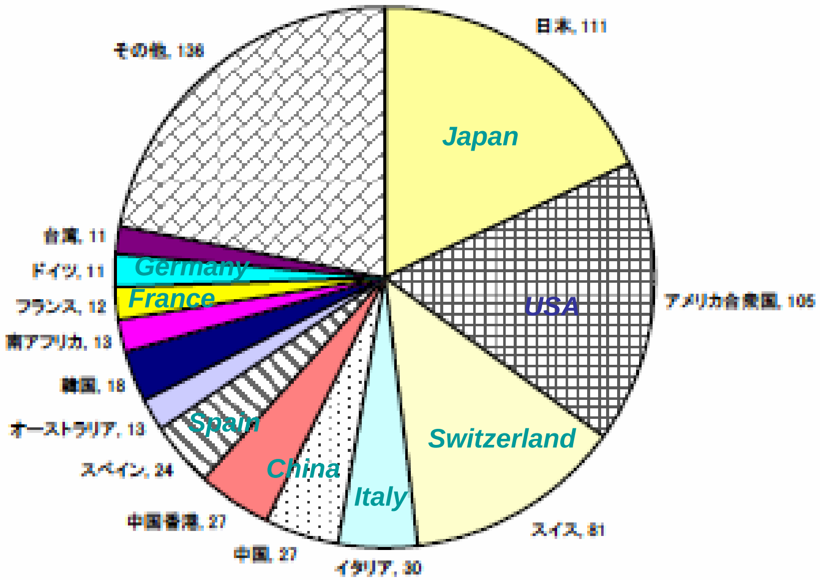


図3.1.2　世界の施工実績の国別件数

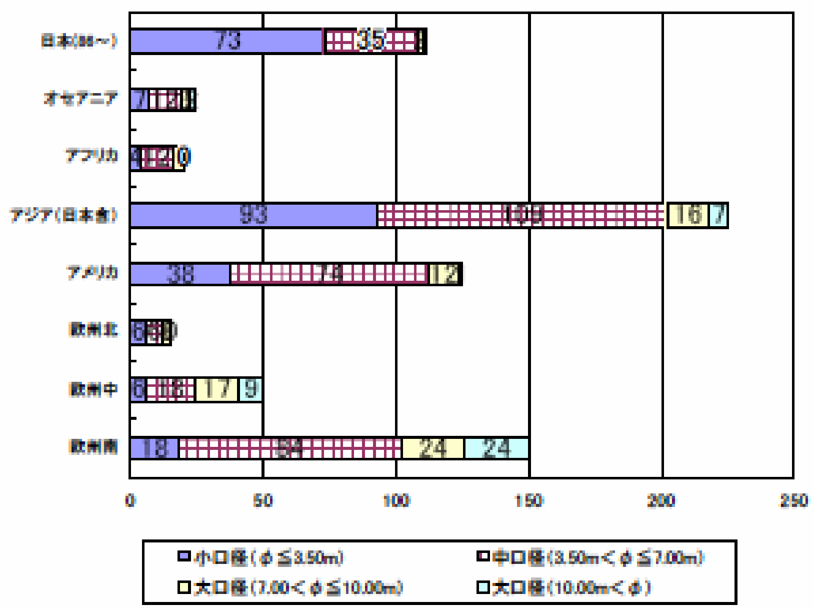
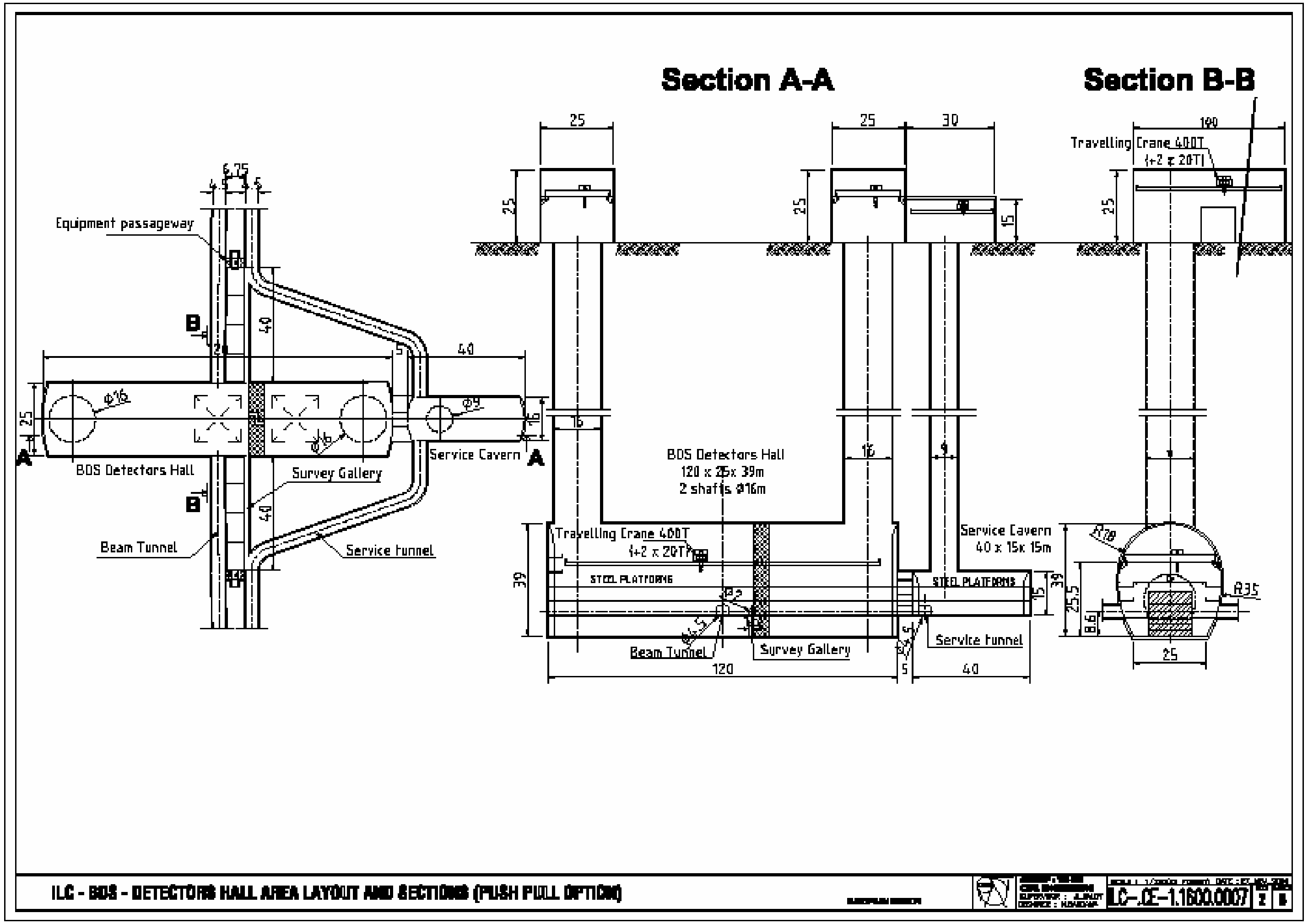


図3.1.7　世界の地域別・径別　施工実績

(From “Current Status of TBM and Rapid Excavation Technology”, Japanese Association of tunneling Technology, Sep. 2006)

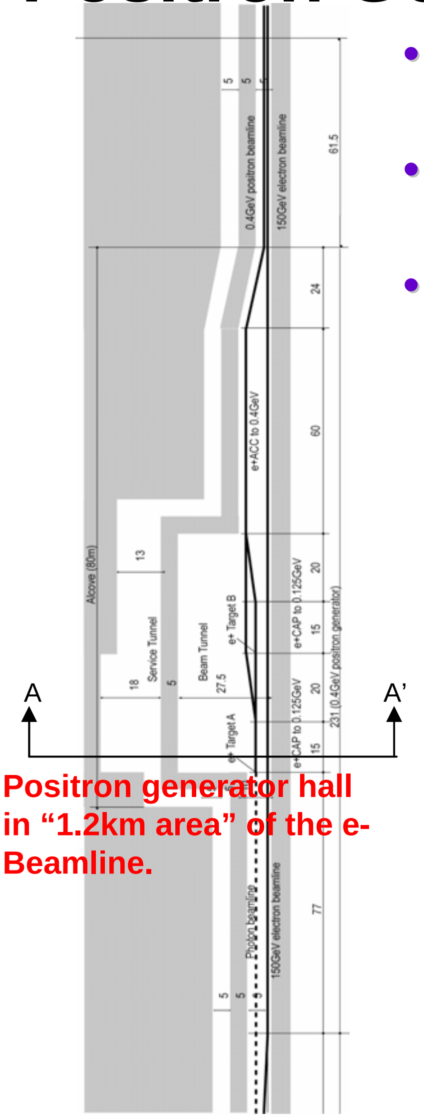
Underground Hall (Cavern)

Detector Hall

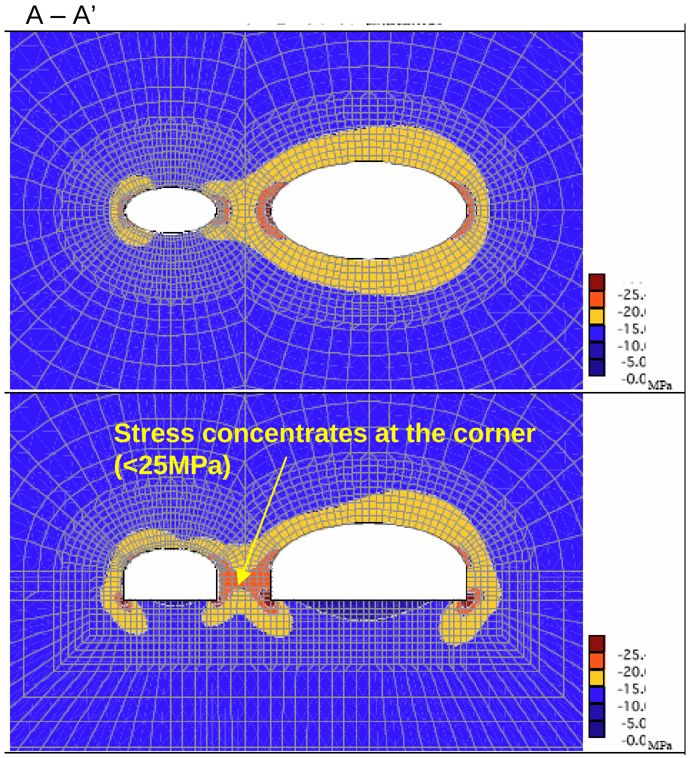


Positron Generator Hall

- *In general oval shape is stable for the section profile for underground structure.*
- *On the other hand, the efficient profile for facility is rectangular shape.*
- *The design depends on the geology.*



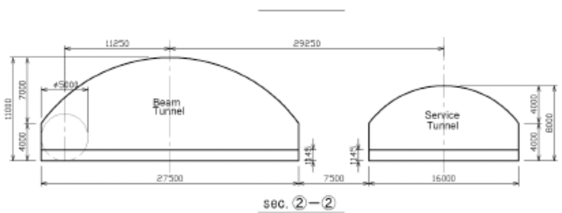
Positron generator hall in "1.2km area" of the e- Beamline.



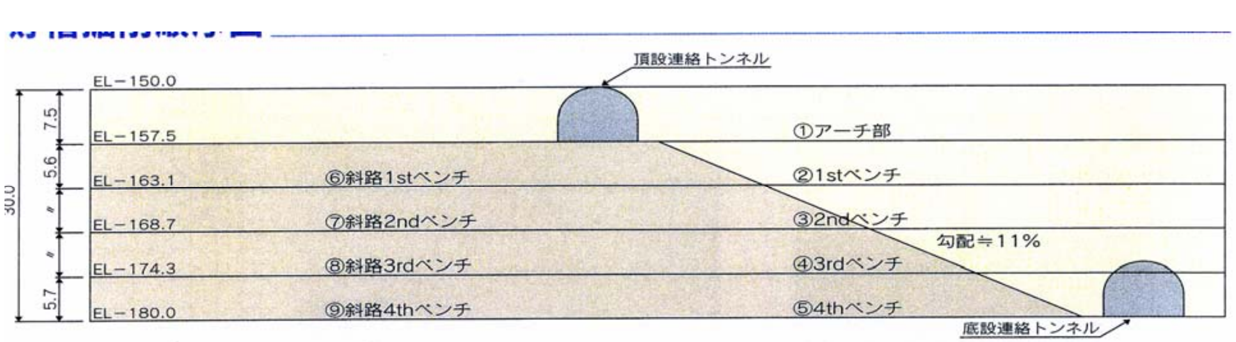
Design example

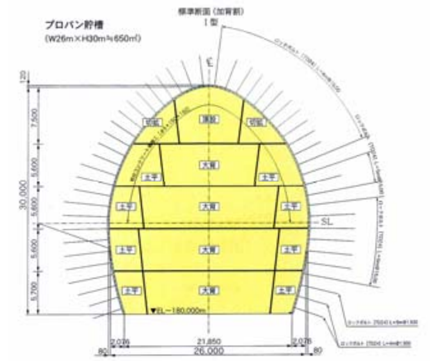
Geology data

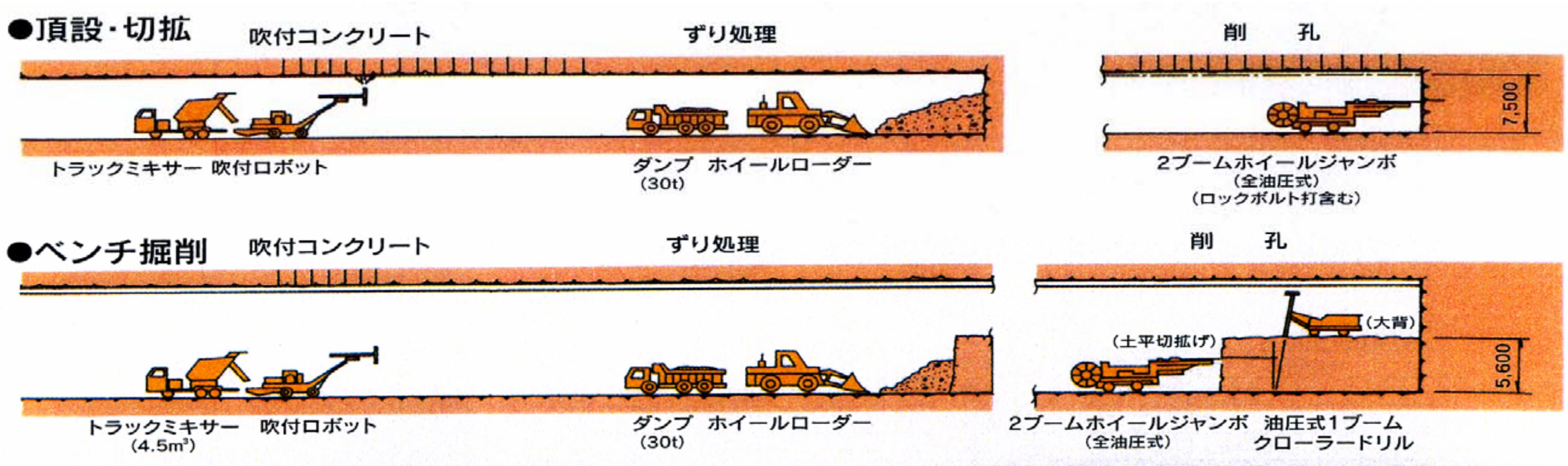
For compressive strength of bedrock ~100MPa (>50MPa)



How to construct Large Hall

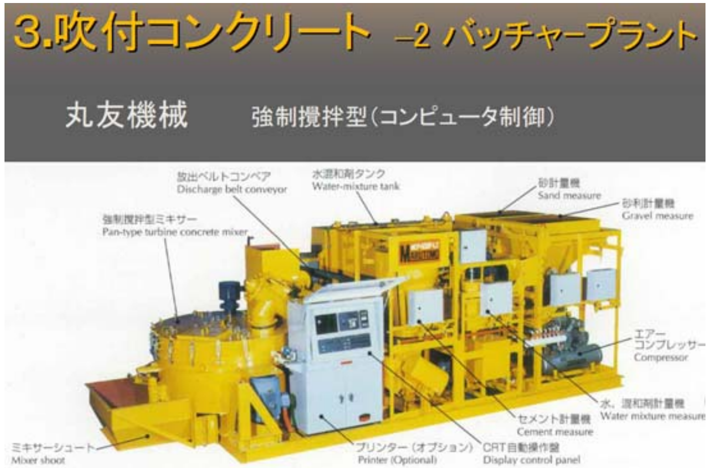






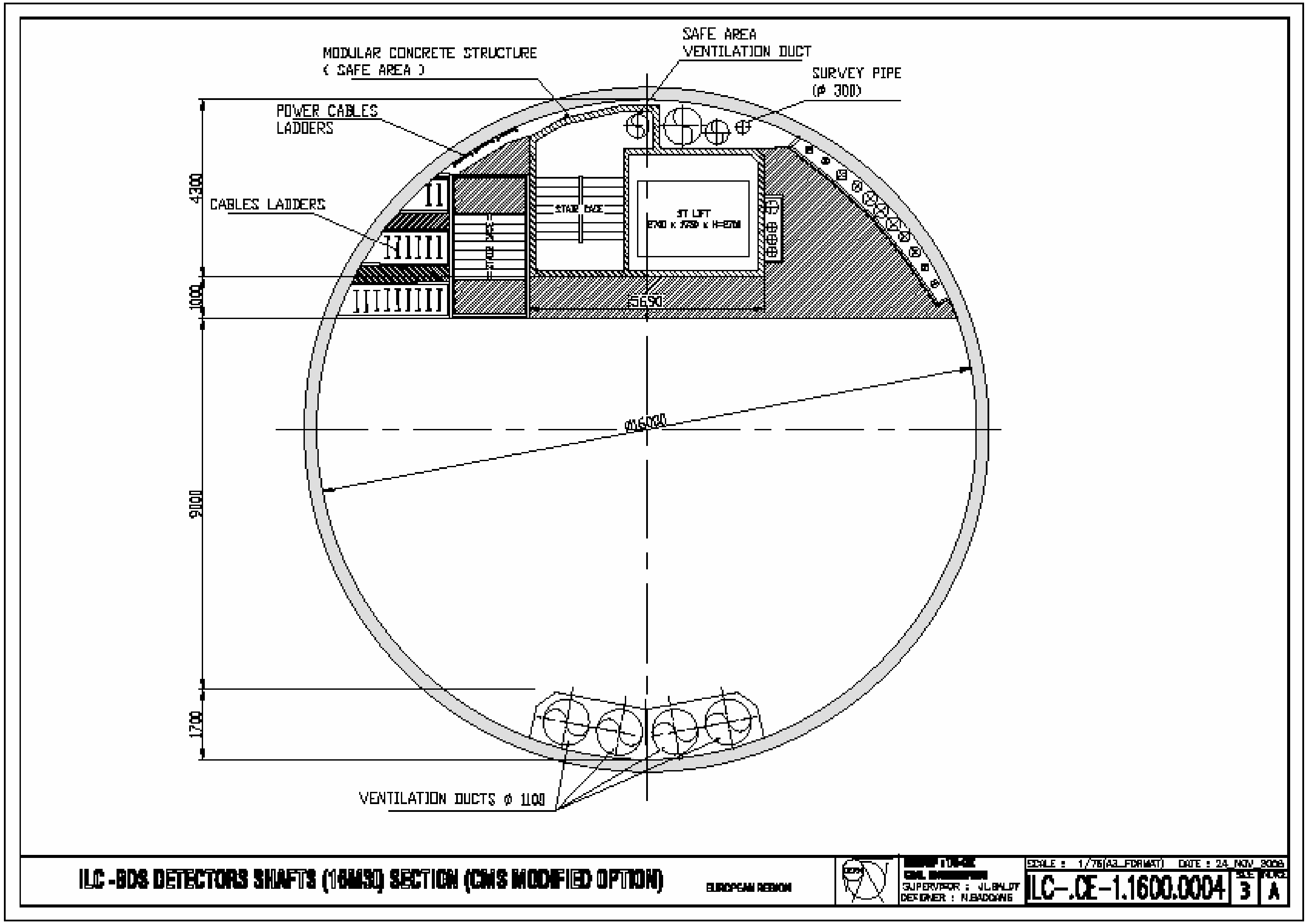
Construction speed = ~1,200 m^3 /week

From materials of Japan Construction Mechanization Association (JCMA).

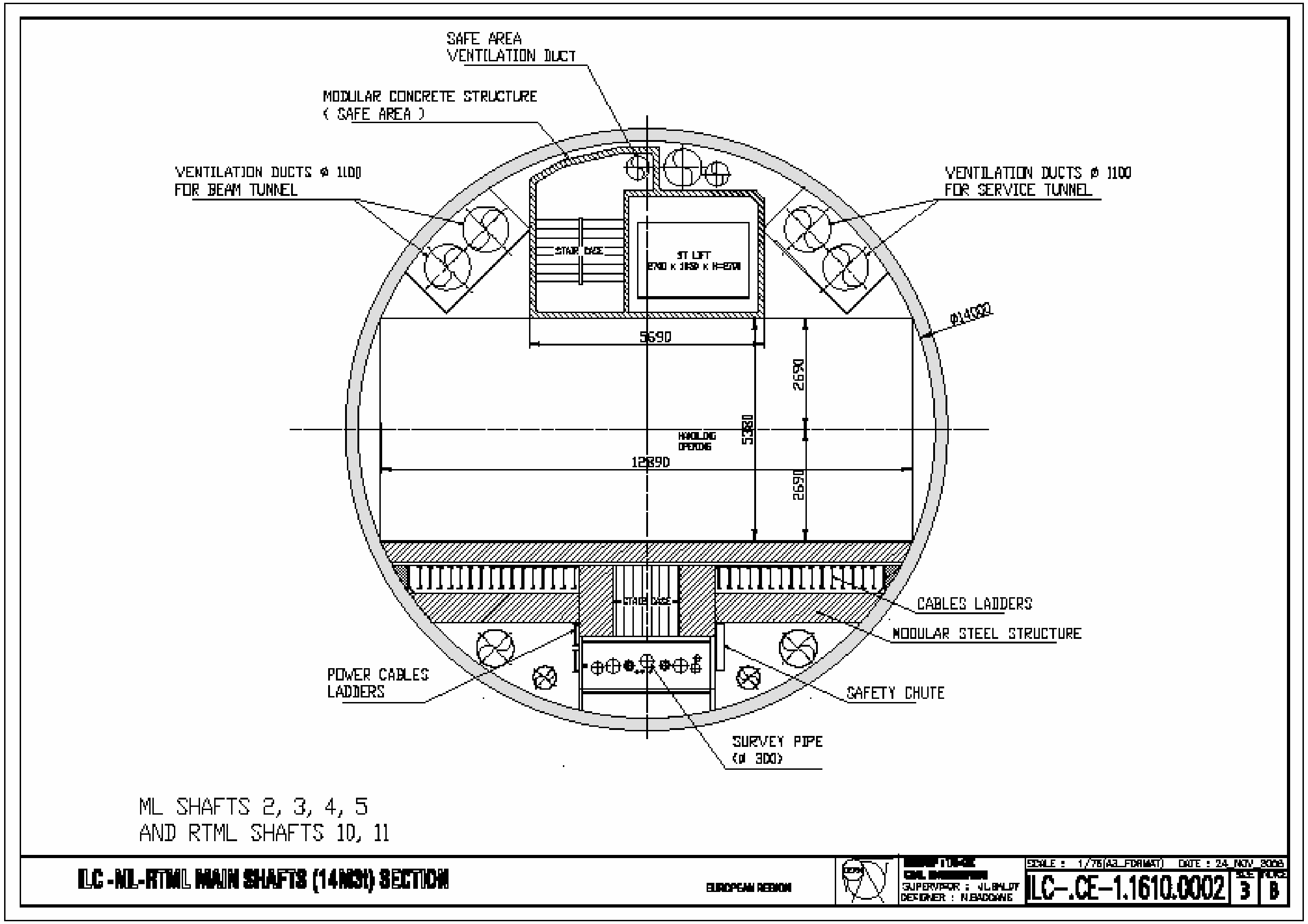


From materials of Japan Construction Mechanization Association (JCMA).

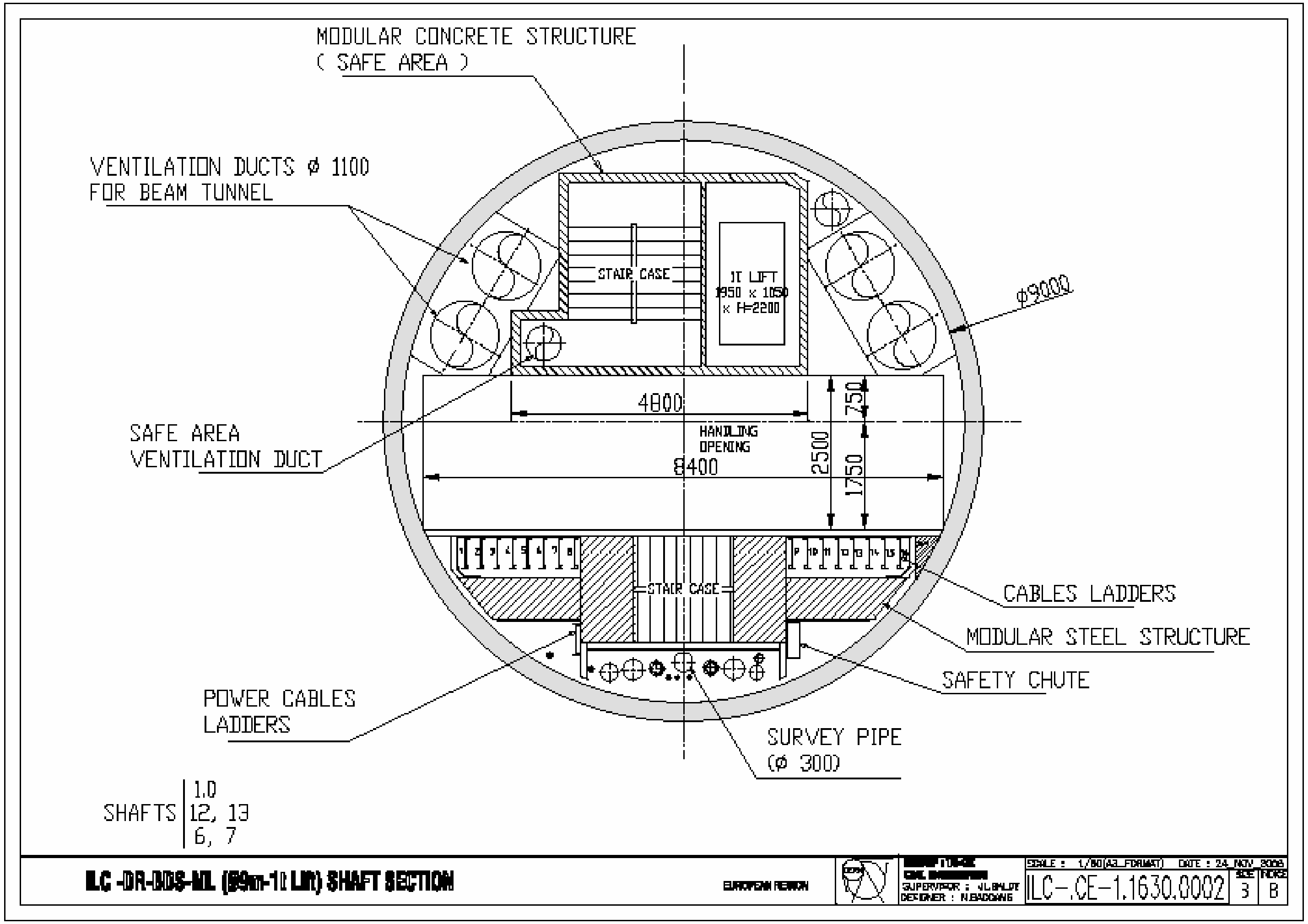
Detector Hall 16mf Shaft



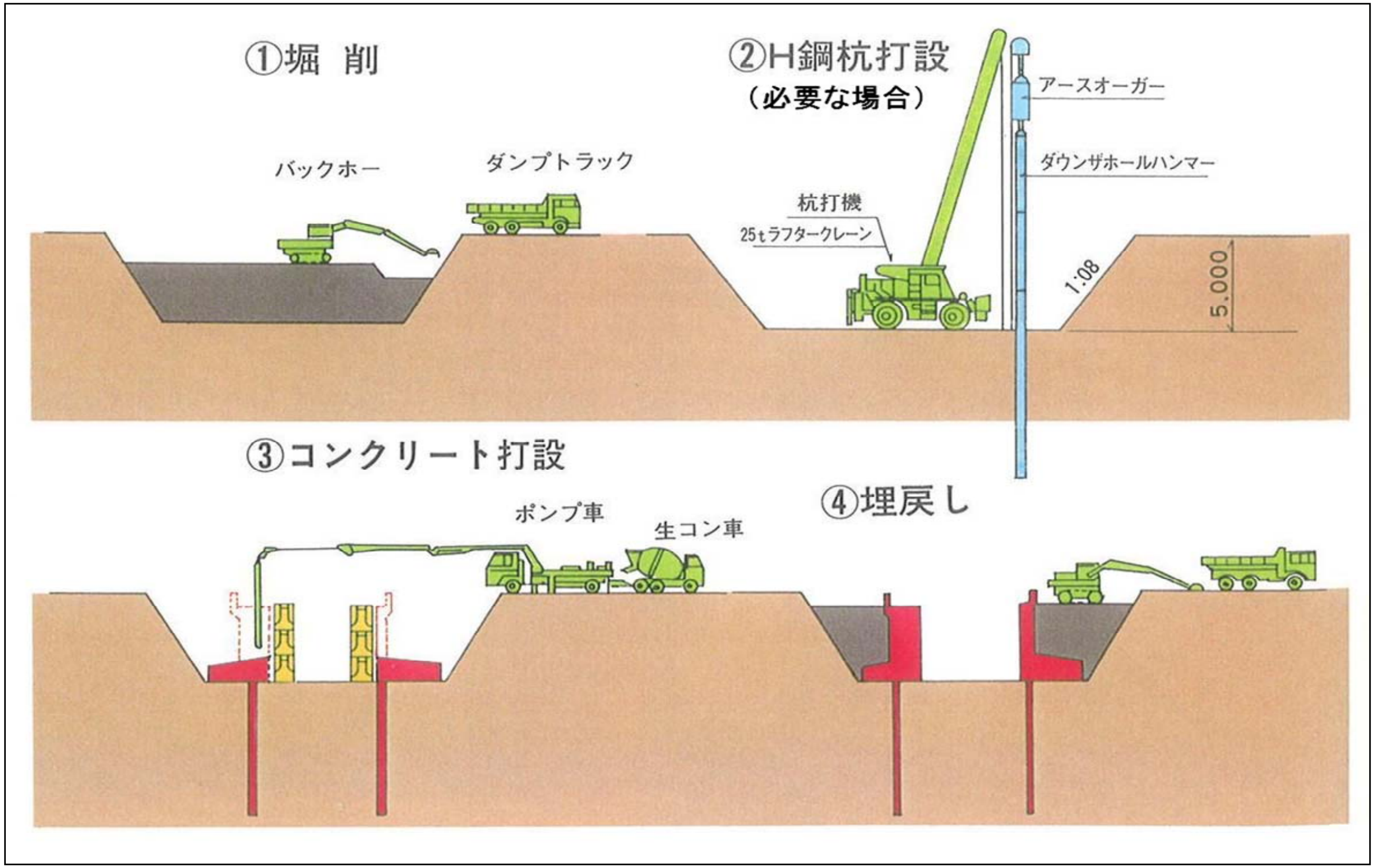
e+Source/ML 14mϕ Shaft at Point 3



9mϕ Shaft at Access Points 1.0, 6, 7, 12, 13



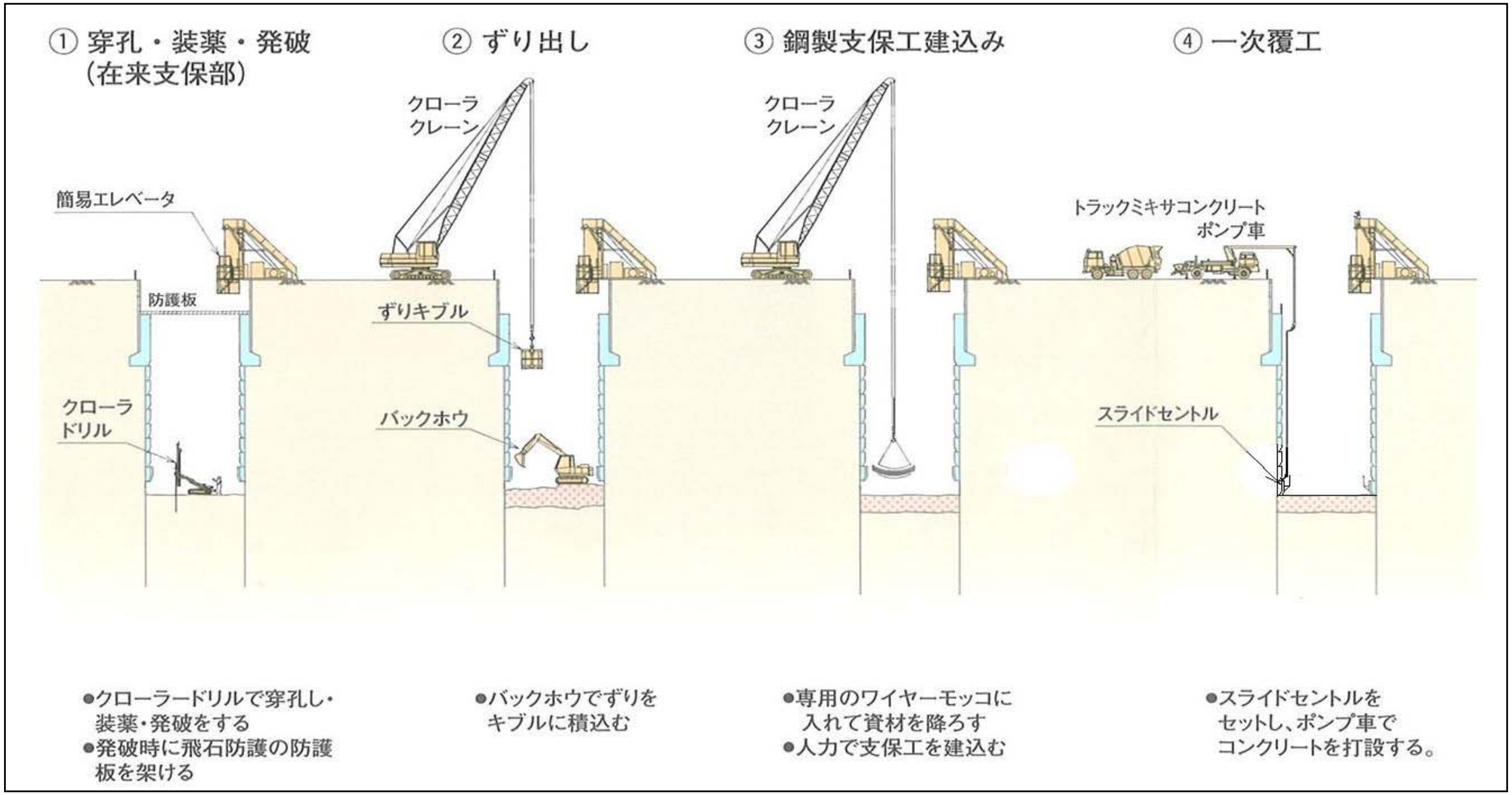
Detector Hall Shaft Construction (0)



~5 month

(From materials of Japan Linear Collider Forum)

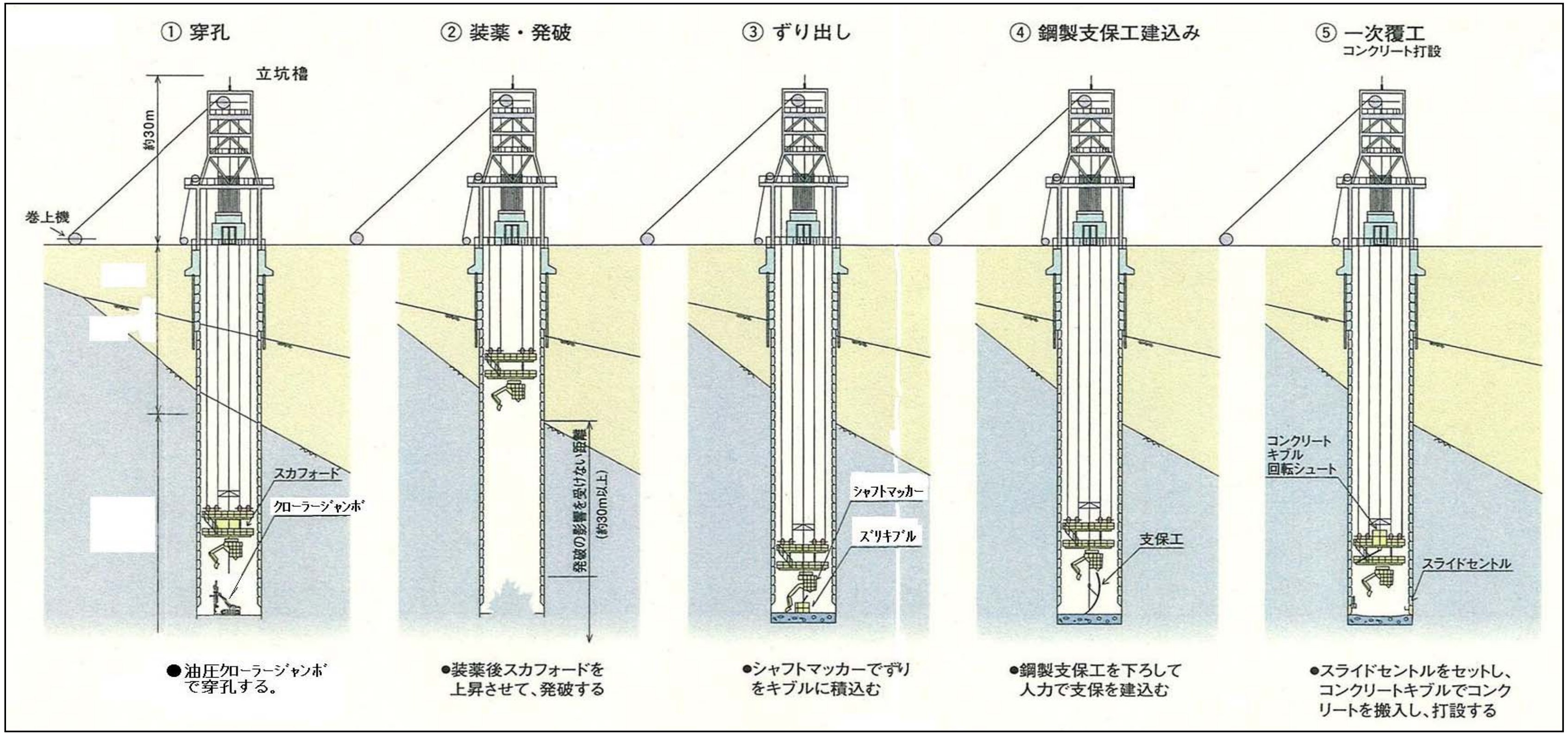
Detector Hall Shaft Construction (1)



(From materials of Japan Linear Collider Forum)

~1.5 month

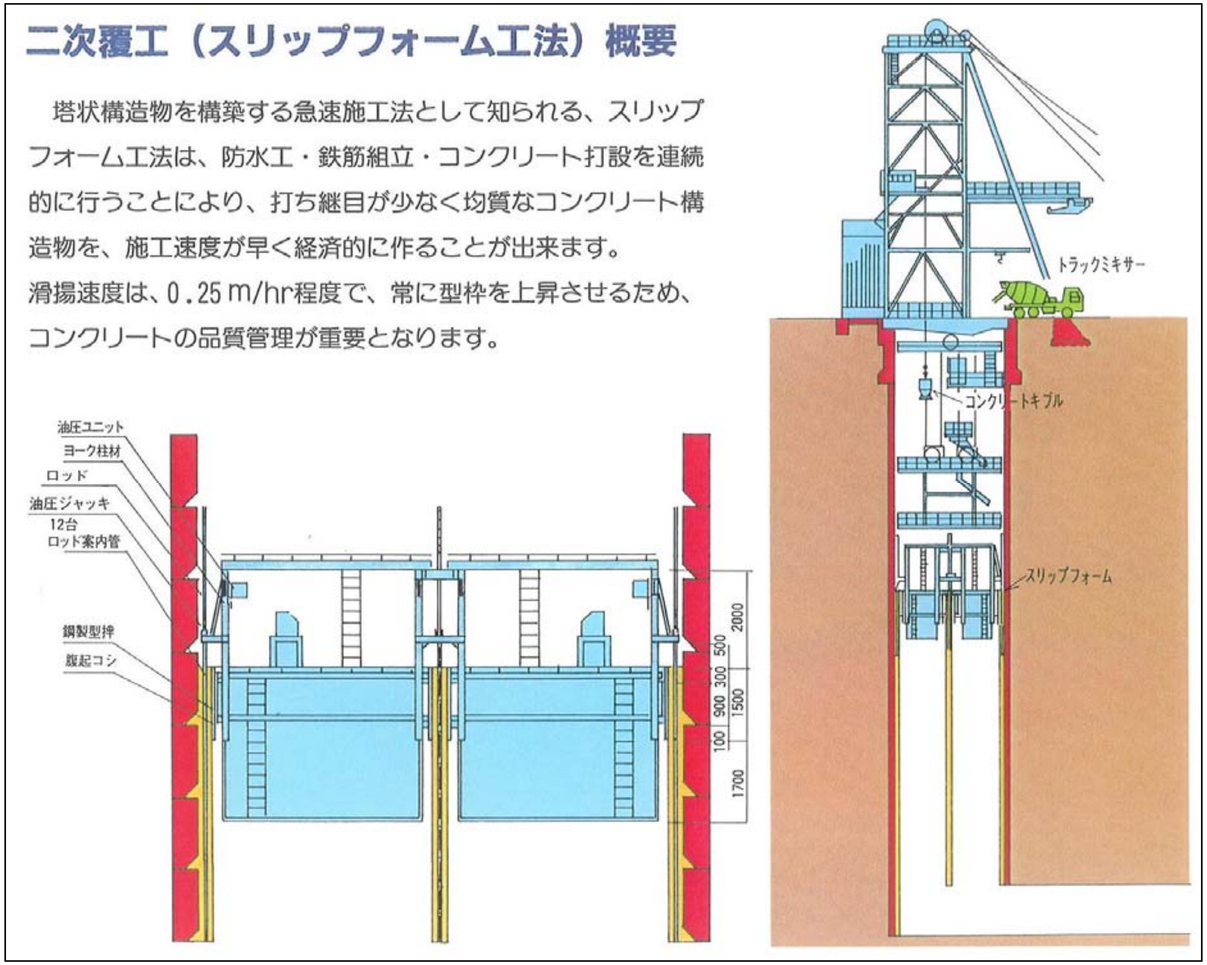
Detector Hall Shaft Construction (2)



(From materials of Japan Linear Collider Forum)

~3 month (prep.) + ~23 m/month (excav.)

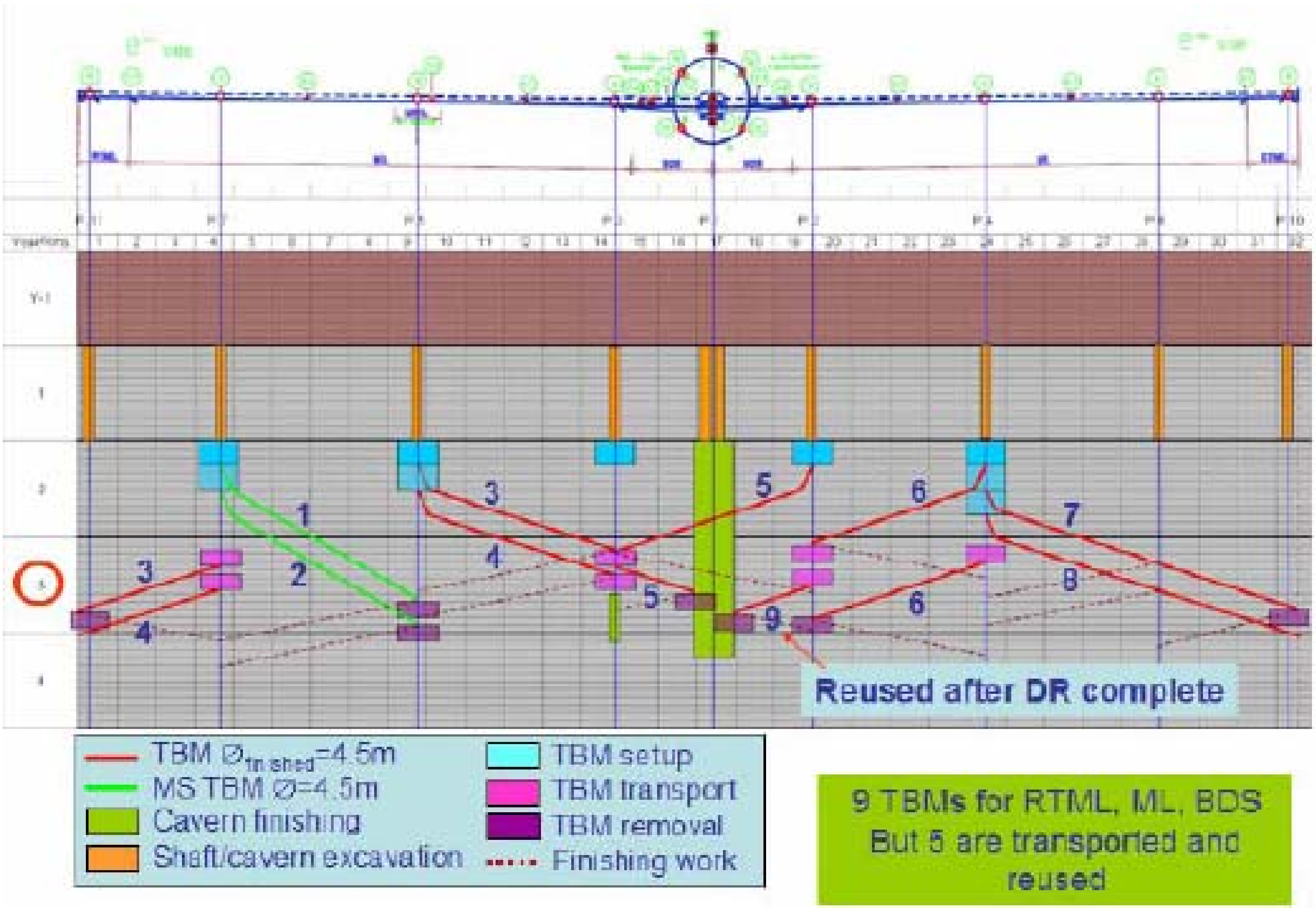
Detector Hall Shaft Construction (3)



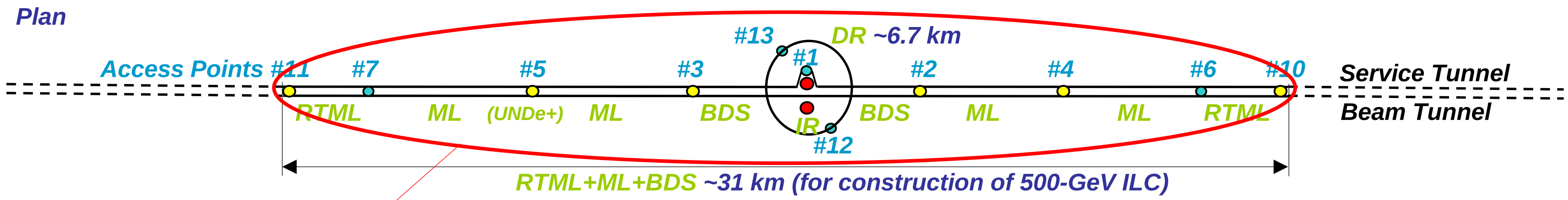
(From materials of Japan Linear Collider Forum)

~1 month (prep.) + ~4 m/day + ~2 month (cln. up)

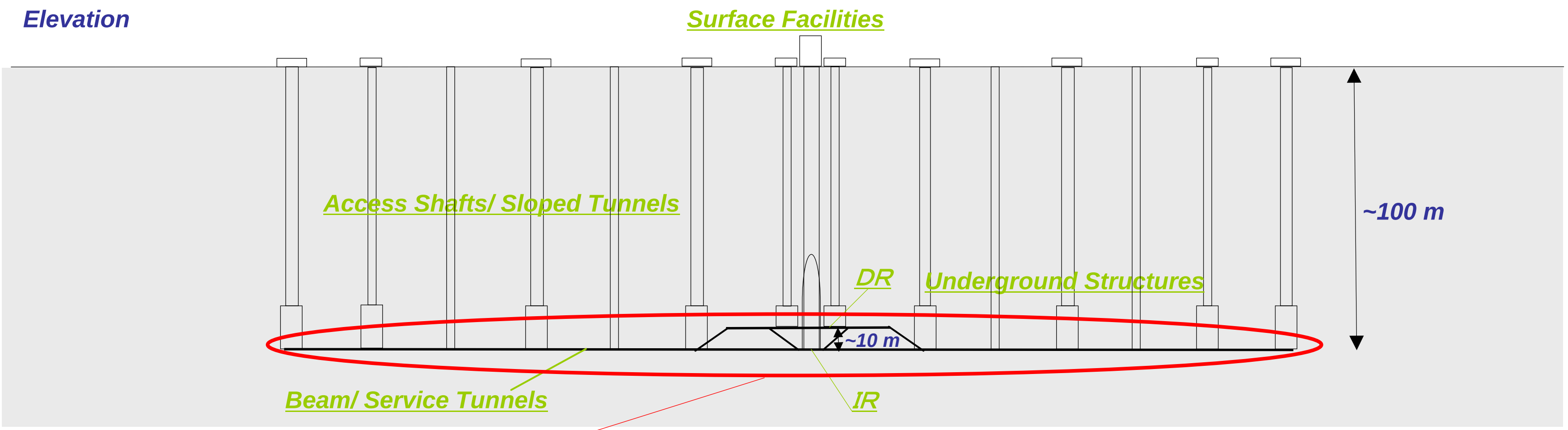
Construction Schedule



Survey and Alignment



- The geodetic reference frame consists of a reference network of approximately 80 monuments that cover the site. These monuments are measured at least twice, by GPS for horizontal coordinates, and by direct leveling for determining the elevations.



- A geodetic reference network is also installed in the tunnel and in the experimental cavern. The reference points in the tunnel are sealed in the floor and/or wall (depending on the tunnel construction), for example, every 50 m. The underground networks are connected to the surface by metrological measurements through vertical shafts. The distance between two consecutive shafts does exceed 2.5 km in most cases.

Survey and Alignment

- ***The components are aligned in two steps:***

  A first alignment is performed to allow connection of the vacuum pipes or interconnection of the various devices. This is done using the underground geodetic network as reference.

  After all major installation activities are complete in each beamline section, a final alignment, or so-called smoothing, is performed directly from component to component in order to guarantee their relative positions over long distances.

TABLE 4.7-1
Component Alignment Tolerances

Area	Type	Tolerance
Sources, Damping Rings and RTML	Offset	150 μm (horizontal and vertical), over a distance of 100 m.
	Roll	100 μrad
Main Linac (cryomodules)	Offset	200 μm (horizontal and vertical), over a distance of 200 m.
	Pitch	20 μrad
	Roll	
BDS	Offset	150 μm (horizontal and vertical), over a distance of 150 m around the IR.

Site requirement

Introduction

- **Site requirements**

  to be able to accommodate all the conventional facilities for the 500 GeV CM machine;

  in addition, the sites needed to have the sufficient length to support an upgrade of the machine to 1 TeV CM, assuming the baseline main linac gradient.

- **Sample site**

  For this reference design, three 'sample sites for the ILC were evaluated.

  There were two reasons for the use of three sample sites for this reference design:

  • This procedure demonstrates that each region can provide at least one satisfactory site for the ILC. This is important, since it shows that any of the regions has the potential to be a host for the project.

  • The cost of, and technical constraints on, the project could depend strongly on the site characteristics. Since the actual site is not yet known, it is important to assess a range of sites with a diverse set of site characteristics, to provide confidence that when the actual site is chosen, it will not present unexpected technical difficulties or major surprises in cost.

Americas Site

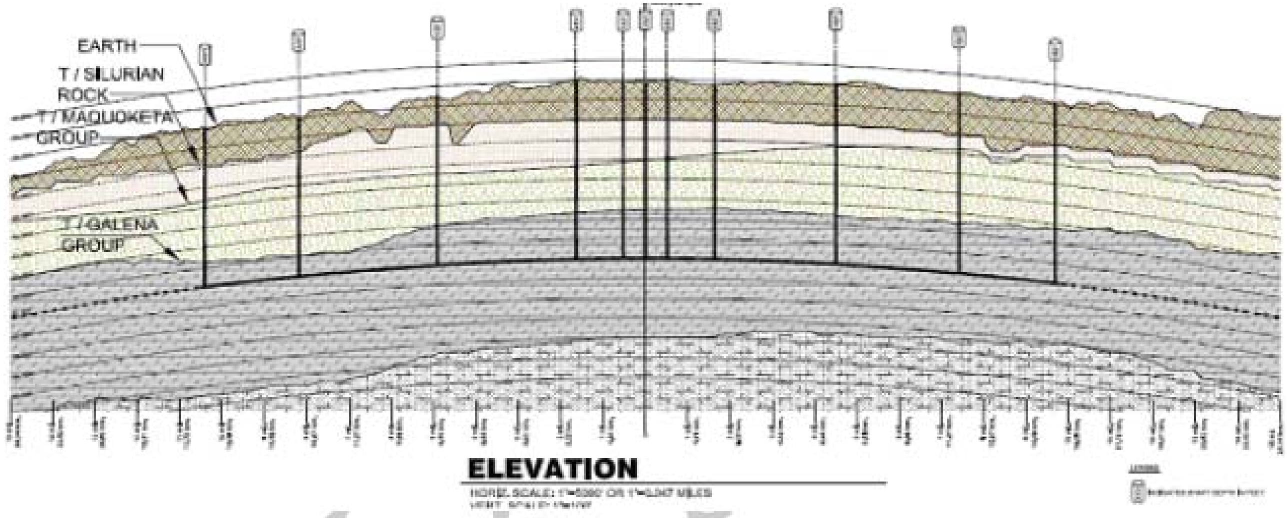


FIGURE 5.2-2. Longitudinal Profile of the Americas Site in Northern Illinois

- ***Geology***

  Galena Platteville layer which is characterized as a fine to medium grained dolomite, that is cherty.

- ***Construction Methods***

  Conventional un-shielded tunnel boring machines are used for the tunnels. Production rate is anticipated to be 30 m/day. Caverns are excavated using drill and blast methods at 1,200 cubic meters per week.

Asian Site

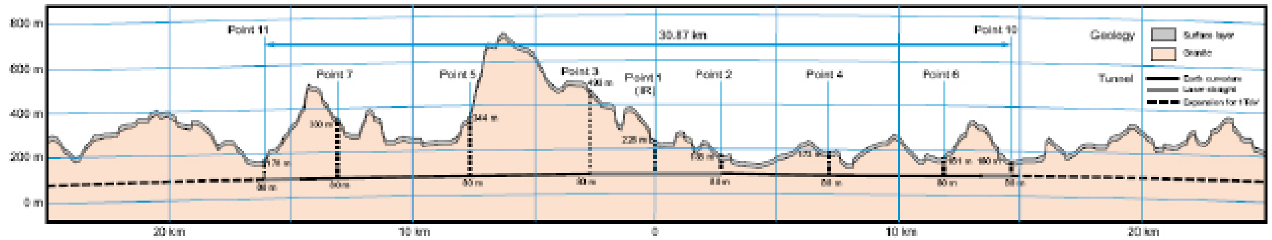


FIGURE 5.3-2. Longitudinal profile of the Asian Sample Site in Japan

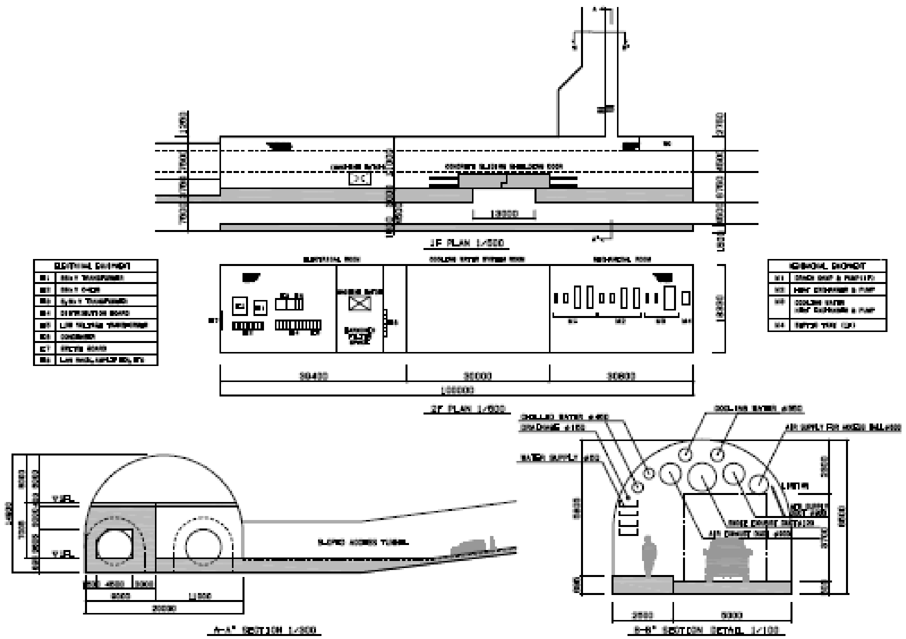


FIGURE 5.3-1. Detail of an access ramp for the Asian Sample Site

- ***Geology***

  Uniform granite which has sufficient strength that the tunnels and caverns do not require reinforcement by rock bolts or concrete lining.bl

- ***Construction Methods***

  The access shafts are sloped tunnels excavated by NATM (New Austrian Tunneling Method). Main tunnels are excavated by TBMs.

European Site

FIGURE 5.4-1. Longitudinal Profile of the European Sample Site near CERN.

- ***Geology***
  - *Most of the proposed path of the ILC is situated within the Molasse, an impermeable sedimentary rock of the Swiss midlands laying over the Jurassic Bedrock.*
- ***Construction Methods***
  - *Shielded Tunnel Boring Machines (TBM-S) with a prefabricated concrete segment lining are used for the long tunnels. An average daily advance of 25 m/day is assumed.*

Summary

TABLE 5.5-1
Summary of notable features of the sample sites and construction methodology.

Subject	Americas Region	Asian Region	European Region
Sample site location	Northern Illinois – near FNAL.	Japan	Geneva Area – near CERN
Land features	200 ~ 240m above sea level	120 ~ 680 m above sea level	430 ~ 480 m above sea level
Geology	Dolomite	Granite (sedimentary rock in phase-2 extension)	Molasse (sedimentary rock / sandstone)
Tunnel depth from surface	100 ~ 150m	40 ~ 600 m	95 ~ 145m (except 1 valley 30 m)
Access paths to underground caverns	13 shafts 9m, 14m, 16m diam 100 ~ 135 m deep	10 sloped tunnels (7.5m × 7m × 700 ~ 2000m) and 3 shafts (for IR)	13 shafts 9m, 14m, 16m diam 100 ~ 135m deep
Tunnel construction	TBM	TBM	TBM
Tunnel lining	20% of length shotcreted	100% of length shotcreted	100% of length precast concrete segments
Average tunnel excavation speed	30m/day/TBM (boring)	16m/day/TBM (boring + surface work)	25m/day/TBM (boring)
Number of TBMs	9	15 (6 out of 9 accesses have two TBMs starting in opposite directions)	9
Cavern construction	Drill and blast	Drill and blast (NATM)	Road breaker /header
Shaft construction	Earth excavation / Drill and blast	Drill and blast (step by step method)	Road breaker/header (Moroccan method)
New surface buildings	92	166	120
Distribution voltage	69/34 kV	66/6.6kV	36kV

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