FUTURE CIRCULAR COLLIDER

FCC Site Investigations for Areas of Geological Uncertainty and Underground Civil Engineering Structures

FCC Feasibility

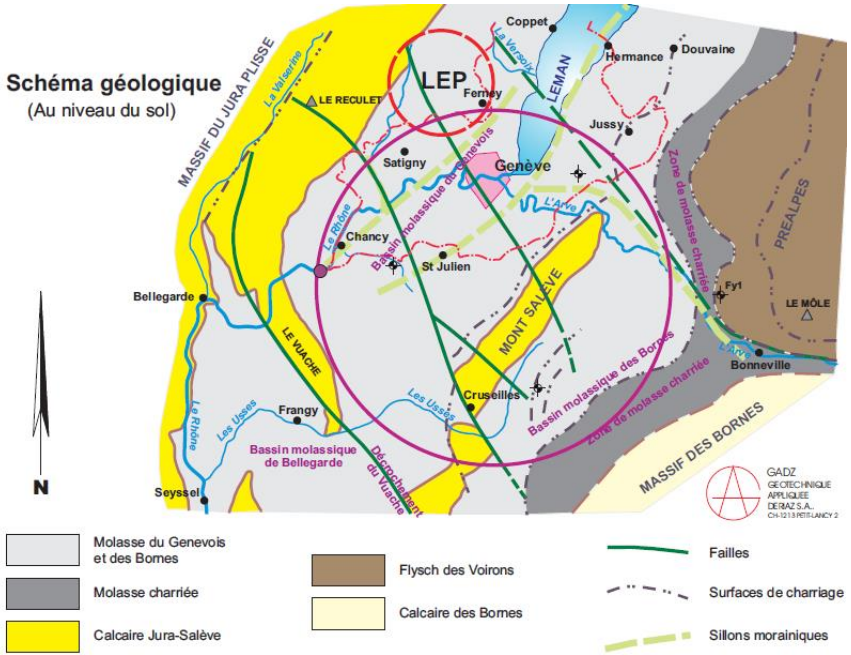
John Osborne SCE-DOD-FS
Roddy Cunningham SCE-DOD-FS
Liam Bromiley SCE-DOD-FS

New people in SCE-DOD-FS Section : Future Studies

Liam Bromiley (liam.bromiley@cern.ch)
Started as Fellow 1 March 2022
100% FCC
Mostly working on FCC underground civil engineering

Roddy Cunningham (roddy.cunningham@cern.ch)
Started as Fellow 1 October 2020 on Tunnel Asset Management
From 1 May 2022 started as staff member on FCC
Gradually building up to 100% FCC
Mostly working on FCC Site Investigations

Geology in the FCC region



Main geological units

Molasse

- Mixture of sandstones, marls and formations of intermediate composition
- Relatively weak rock (Average compressive strength: 5.5-48 Mpa)
- Considered good excavation rock
- Relatively dry and stable
- Faulting due to the redistribution of ground stresses
- Structural instability (swelling, creep, squeezing)

Moraines (Quaternary Deposits)

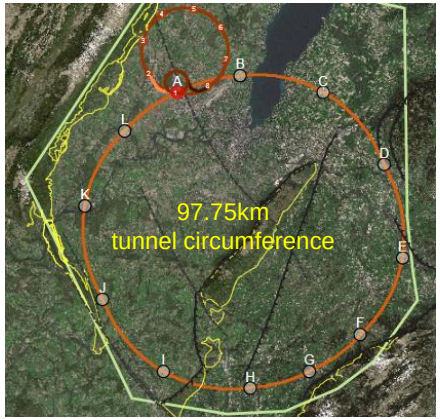
- Glacial deposits comprising gravel, sands silt and clay
- Water bearing unit

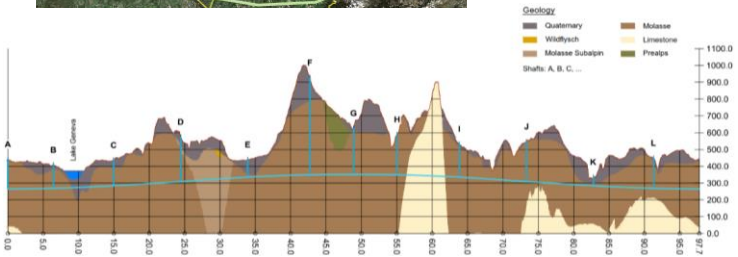
Limestone

- Hard rock
- Normally considered as sound tunneling rock
- In this region fractures and karsts likely present
- High inflow rates measured during LEP construction (600L/sec)
- Clay-silt sediments in water
- Rockmass instabilities

Tunnel Alignment Developments since CDR

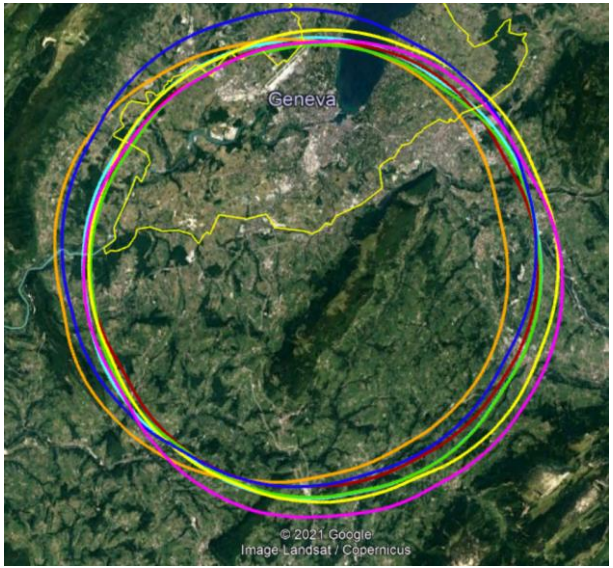
Conceptual Design Layout (2018-2019)





Several scenarios analysed, investigating surface constraints and geological risks (2019-2021)

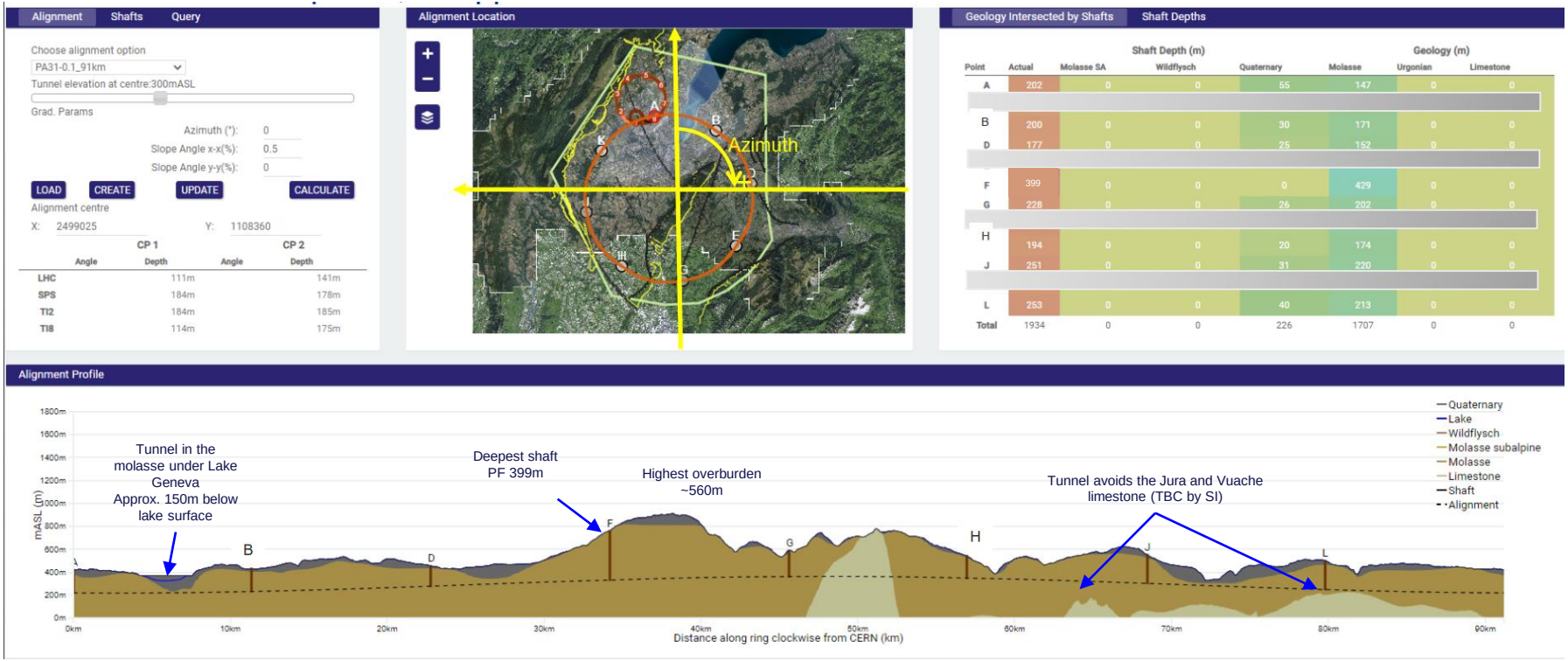
Scenarios reviewed at the Placement Workshop on 7 June 2021



***Including the study of 12 points and 8 points scenarios. Impact of changing to 8 points not yet studied by CE e.g. Cost & Schedule**

Conclusions from the Placement Review Workshop

Selected scenario to be studied: **91km PA31-1.0 (8 points)**



Main civil engineering objectives for the Next European Strategy

ESPPU 2020:

More comprehensive feasibility study to be delivered end 2025 as **input for ESPP Update expected for 2026/2027**:

- ***Feasibility study of the 100 km tunnel***
- ***Site investigations at areas of geological uncertainty****, to confirm principal feasibility -* ***10-15 MCHF budget***
- ***Feasibility Study Report*** *including design and cost and schedule updates*

To achieve these objectives, the CERN civil engineering team are launching a site investigation campaign for Areas of Geological Uncertainty for FCC.

Areas of Geological Uncertainty include:

- *Locations along the FCC tunnel alignment where there is high uncertainty in the geological boundary layers and ground conditions, critical to determine the vertical and the horizontal alignment of the FCC tunnel.*
- *Areas to avoid where the complexity of the ground and hydrogeological conditions would dramatically increase the costs/risks during construction works and/or maintenance*

The main objective of the civil engineering underground HRASI campaign is to establish the tunnel alignment and confirm the tunnel feasibility. Assuming funding approval, the HRASI will be followed by the Main Site Investigation (MSI) required to establish a geotechnical basis for design and construction. The cost estimate for the whole site investigation campaign for FCC project is estimated to be ~100 MCHF.

ILF/GADZ study of Areas of Geological Uncertainty

- Definition of ‘Areas of Geological Uncertainty’ for the preferred scenario(s)
- Input into footprint exploration –Comparison of scenarios and Geological Risks Assessment
- Propose site investigations in the HRA to reduce the uncertainty of the geological condition
- Cost estimates and schedule of the SI in the HRA
- Procurement strategy for HRASI and MSI
- Input into the Technical Specifications to define the Scope of Services for the SI Consultants and cost estimate and schedule of the deliverables of SI Consultants
- ILF/GADZ study was focused on the construction risks for underground works and not the impact on machine operations or the environmental impact

Areas of Geological Uncertainty

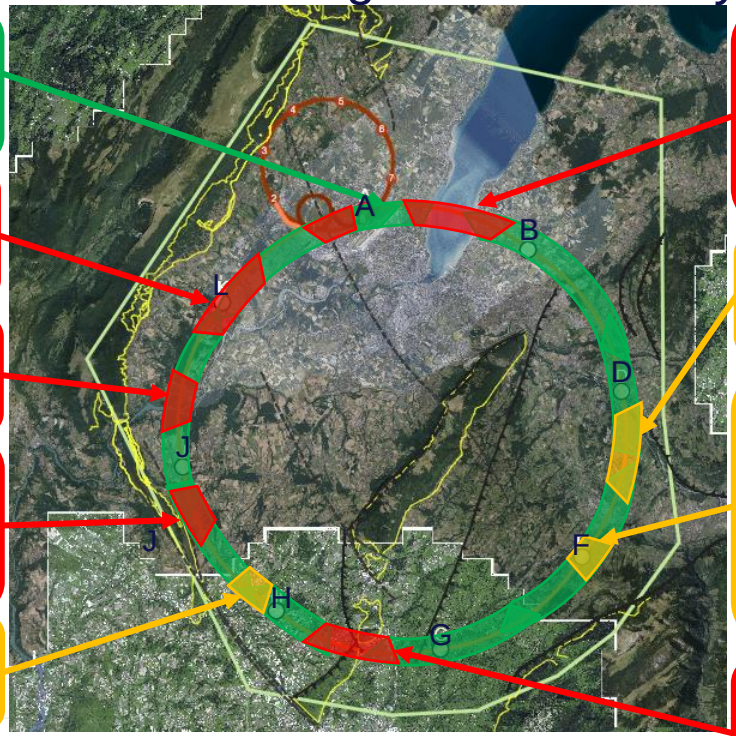
- Good knowledge of the ground (e.g. information near to CERN from LEP/LHC projects)
- Good confidence that the tunnel alignment is in molasse

Jura
- Limestone/molasse interface uncertain.
- Risk of karts and high water pressures

Le Rhône
- Moraine/molasse interface not certain.
- Proximity to protected area

Vuache
- Limestone/molasse interface not certain.
- Risk of karts and high water pressures
- Proximity to main active fault

Les Usses
- Moraine/molasse interface not certain.
- Low tunnel rock cover

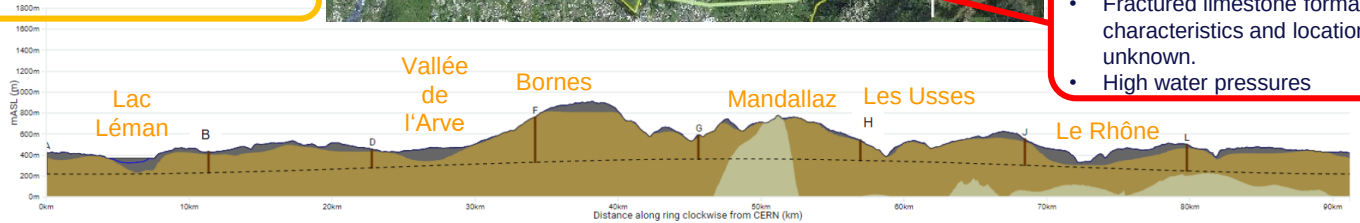


Lac Léman
- Moraine/molasse interface uncertain
- Soils and rock properties uncertain
- High uncertainty in the hydrogeological conditions and water pressure

Vallée de l'Arve
- Moraine/molasse interface uncertain.
- Lack of reliable boreholes

Bornes
- Insufficient deep boreholes information
- Complex faulted region, thrust zone.
- Quality of molasse is uncertain. High overburden. Large span experimental caverns should be constructed in good molasse.

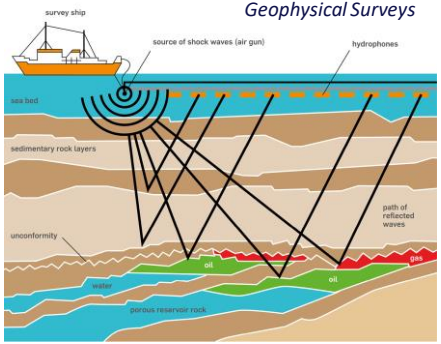
Mandallaz
- Fractured limestone formations, characteristics and locations of karsts unknown.
- High water pressures



Types of Site Investigations

Exploration Drilling, CERN 2020

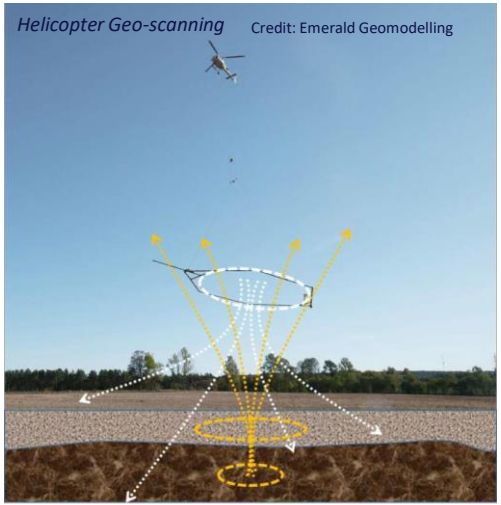
Lake Geneva Geophysical Surveys



Lake Geneva Drillings

SIG Geophysics campaign 23.09.2021

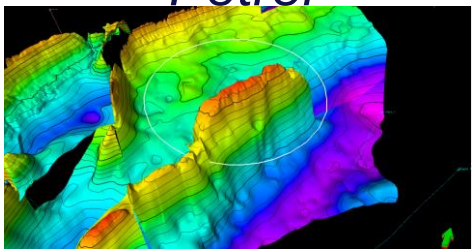
Helicopter Geo-scanning Credit: Emerald Geomodelling



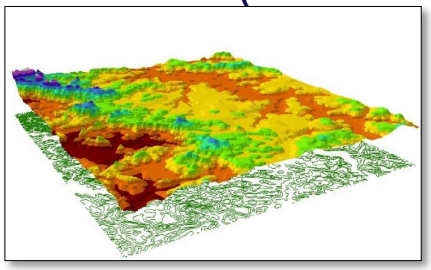
UNIGE geological model

Collaboration with University of Geneva to develop a 3D geological model (October 2020 - Ongoing)

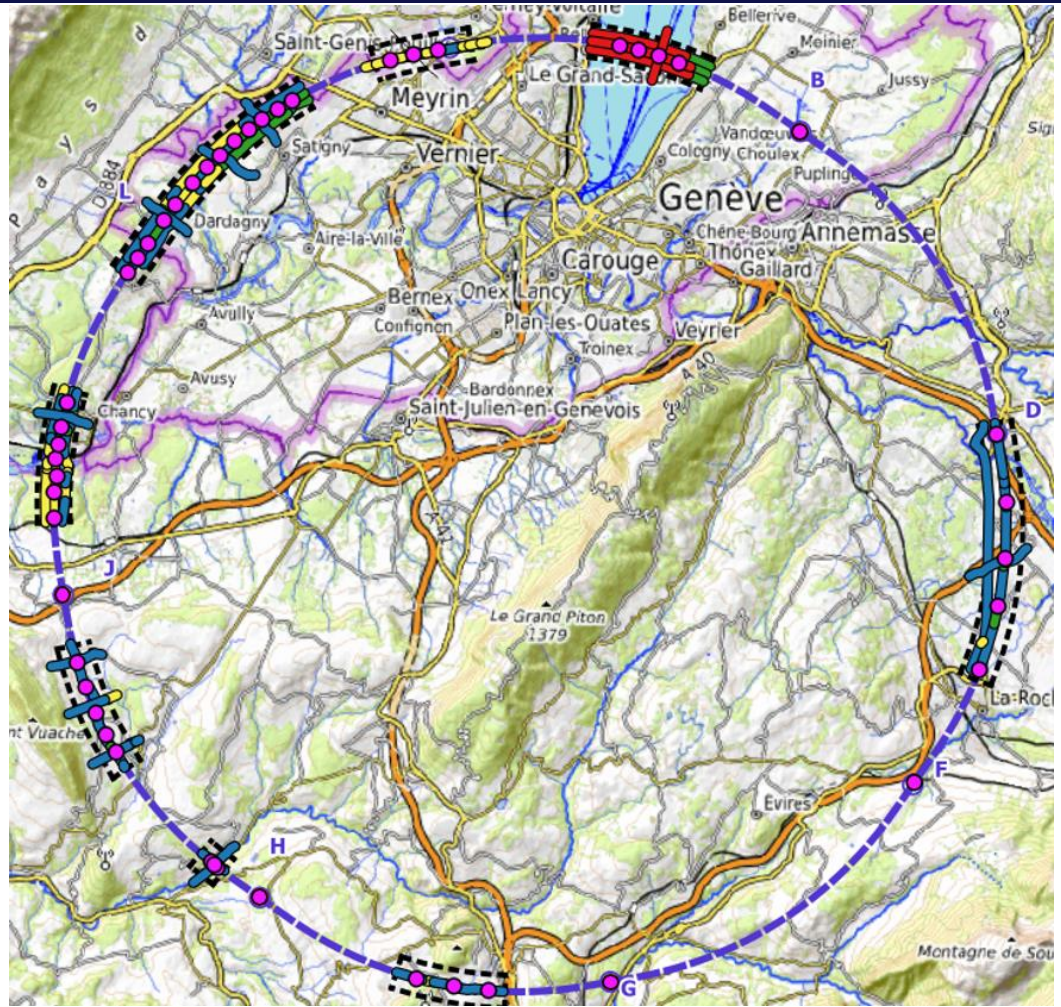
Petrel



SOLSTISS (GESDEC)

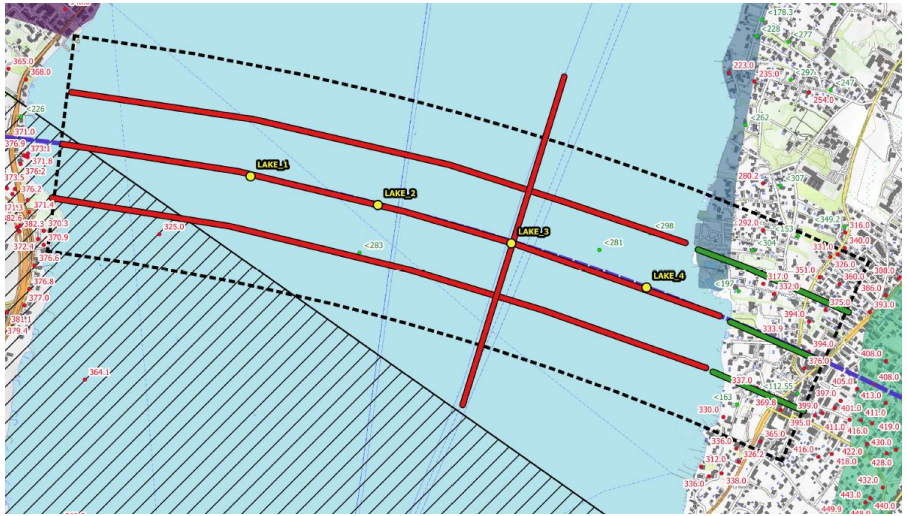


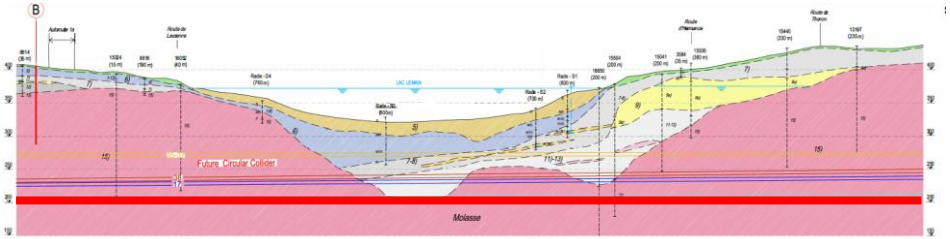
- Received an updated molasse and limestone rockhead maps
- Updated fault lines layers
- Ongoing analysis of new boreholes and data integration in the model
- New acquisition of BRGM seismic lines and reprocessing



Overall site investigation campaign proposed in tender

SI DEFINITION – LAKE GENEVA





3 seismic reflection lines parallel to the alignment
1 seismic reflection line perpendicular to the alignment

4 fully cored boreholes

Quantities (geophysics)

The total length of the seismic lines in the HRA is ~ 91.25 km.

Area	No of 2D lines	Total length source line (m)	Depth of investigations (m)
Jura 1	6	27870	400
Jura 2	2	5777	350
Lake Geneva	4	12911	100
Arve Valley	3	17456	150
Mandallaz	2	2489	100
Usses	1	3337	500
Vuache	4	8960	700
Rhone Valley	4	12450	250
Total length of lines (m)		**91250**	

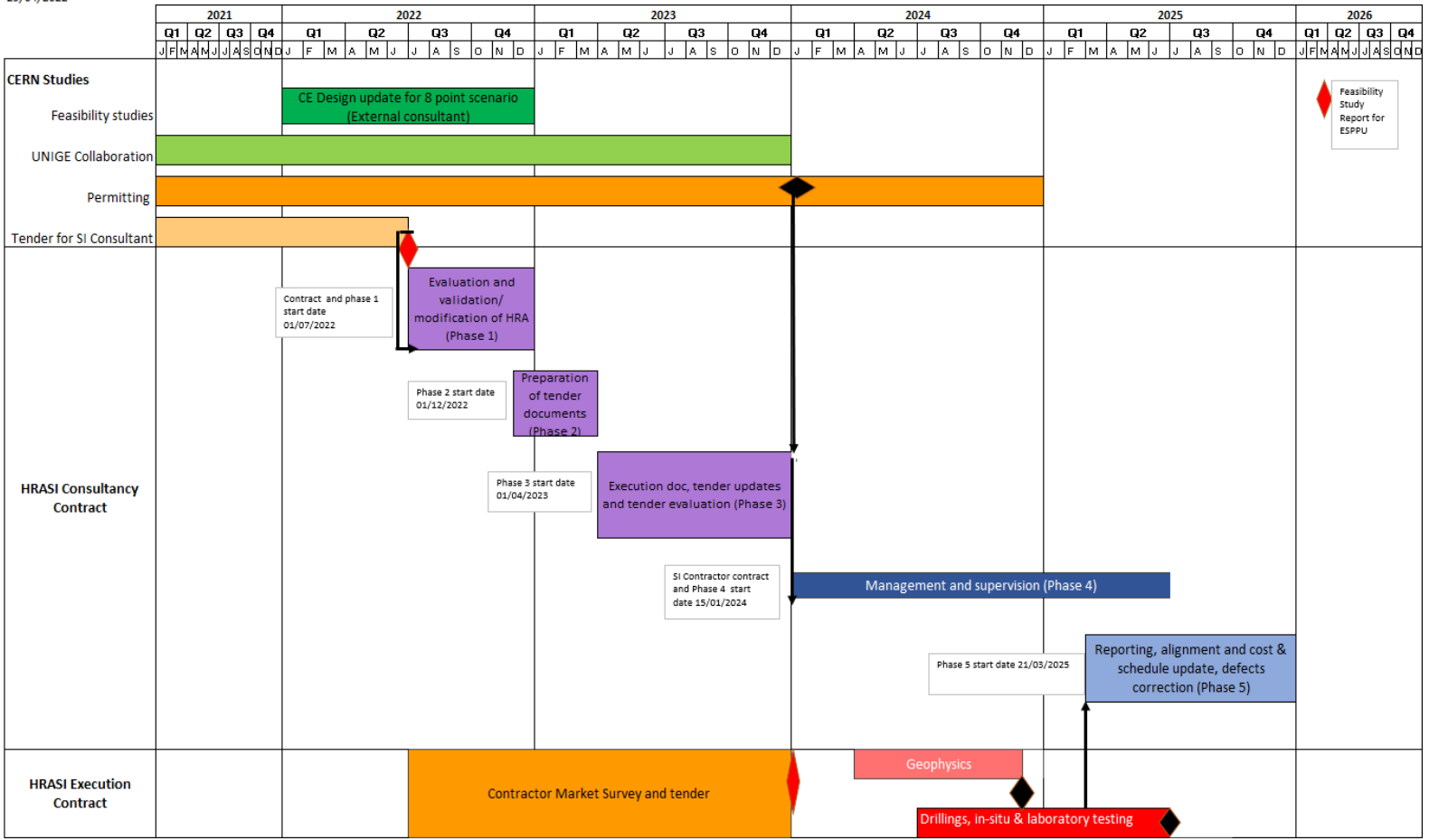
Quantities (boreholes)

The total length of the proposed boreholes in the HRA is ~10km including 44 boreholes of which 11 are fully cored and 33 destructive (partially cored).

Area	BOREHOLE LENGTH (m)			BOREHOLE LENGTH / FCC (m)			PRESUMED GROUND LAYER (m)		
	TOT.	DEST.	CORED	BORED UNDER FCC	CORED OVER FCC	CORED UNDER FCC	QUAT.	MOLASSE	CRET.
JURA1	3590	2980	610	630	300	160	435	3030	90
JURA2	775	425	350	160	230	105	125	640	0
LAKE	550	0	550	65	485	65	360	170	0
ARVE	950	540	410	105	305	105	415	530	0
MANDALLAZ	1170	0	1170	95	1075	95	70	600	500
USSES	215	65	150	45	105	45	95	120	0
VUACHE	1475	1270	205	270	55	105	165	1280	0
RHONE	845	495	350	140	210	140	605	230	0
BORNES	460		460	35	425	35	30	430	-
TOTAL	**10030**	**5775**	**4255**	**1545**	**3190**	**855**	**2300**	**7030**	**590**

HRASI Programme

Version 1.3
29/04/2022



Key milestones

SI Consultant	Date
Consultants Specification Committee meeting	17 November 2021
Dispatch of IT documents	13 - 17 December 2021
Bidder’s conference	21 January 2022
Submission deadline for bidders	End of February 2022
Bid evaluation/clarification/negotiation	End of March 2022
FC paper issued for approval	End of April 2022
Date of FC meeting	14 - 15 June 2022

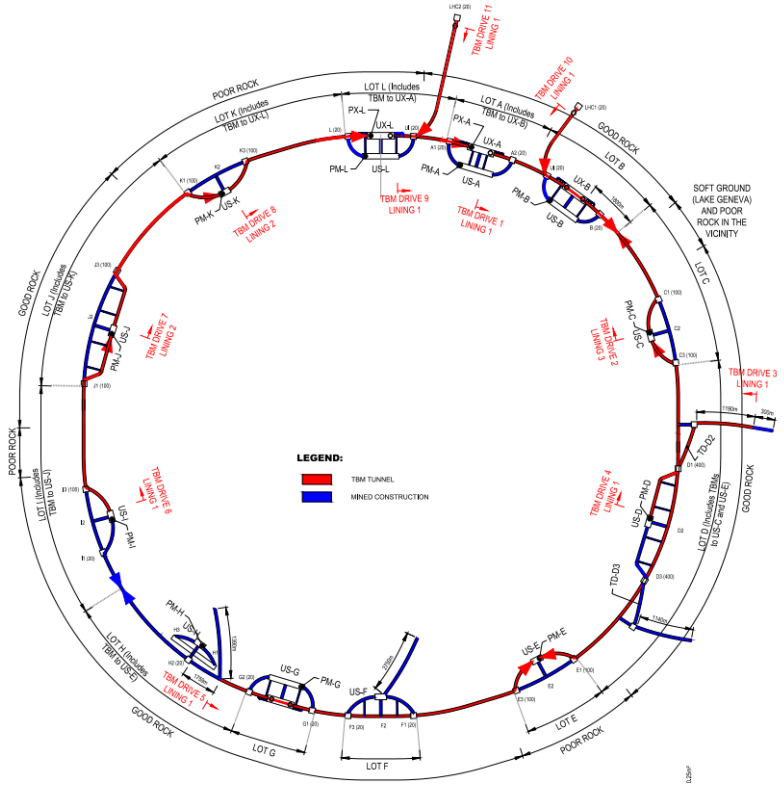
Key milestones

MS Contractor	Date
Departmental request	June 2022
Finalisation of draft MS documents	August 2022
Technical auditing of MS documents	September/October 2022
Dispatch of MS documents	August 2022
Analysis of responses and selection of firms	February 2023

IT Contractor	Date
Finalisation of IT documents	End of March 2023
Specification Committee meeting	April 2023
Dispatch of IT documents	May 2023
Bidder’s conference	+ 2 weeks
Submission deadline for bidders	End of August 2023
FC paper issued for approval	October 2023
Date of FC meeting	December 2023

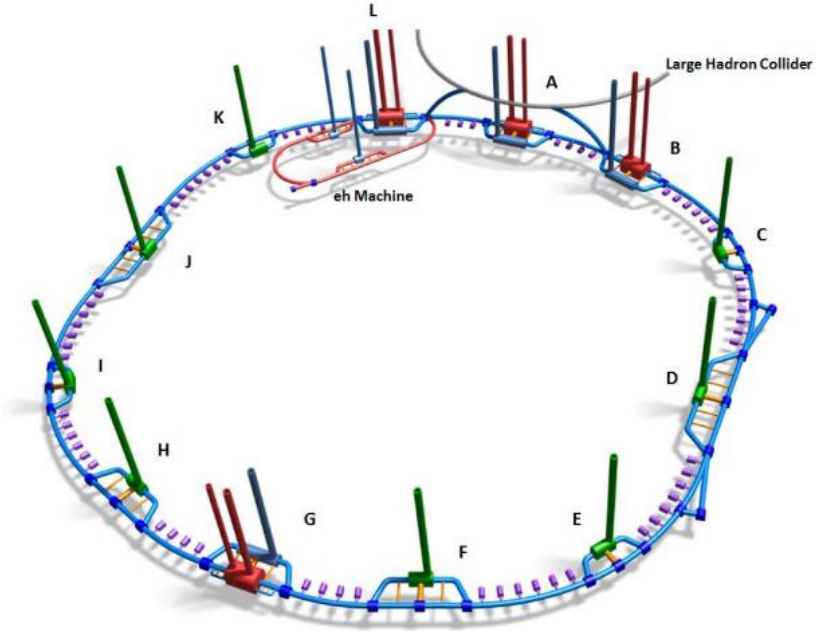
CDR – 12 Point FCC

Schematic



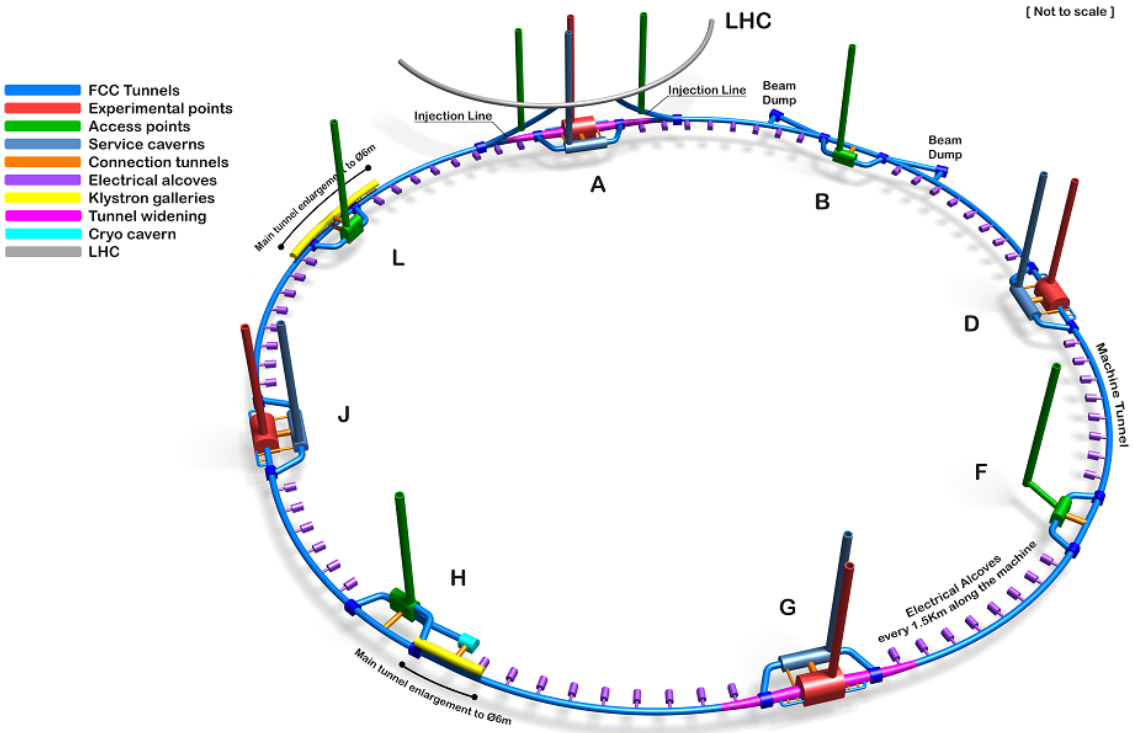
12 Point FCC

- 9 km between points
- Injection tunnels 4.7 km and 7.1 km lengths
- Beam dump at Point D
- Point F inclined access tunnel
- 4 Experiment sites
- 8 technical sites
- 1 Klystron Gallery at Point H only (162m long)



Revised – 8 Point FCC

Schematic

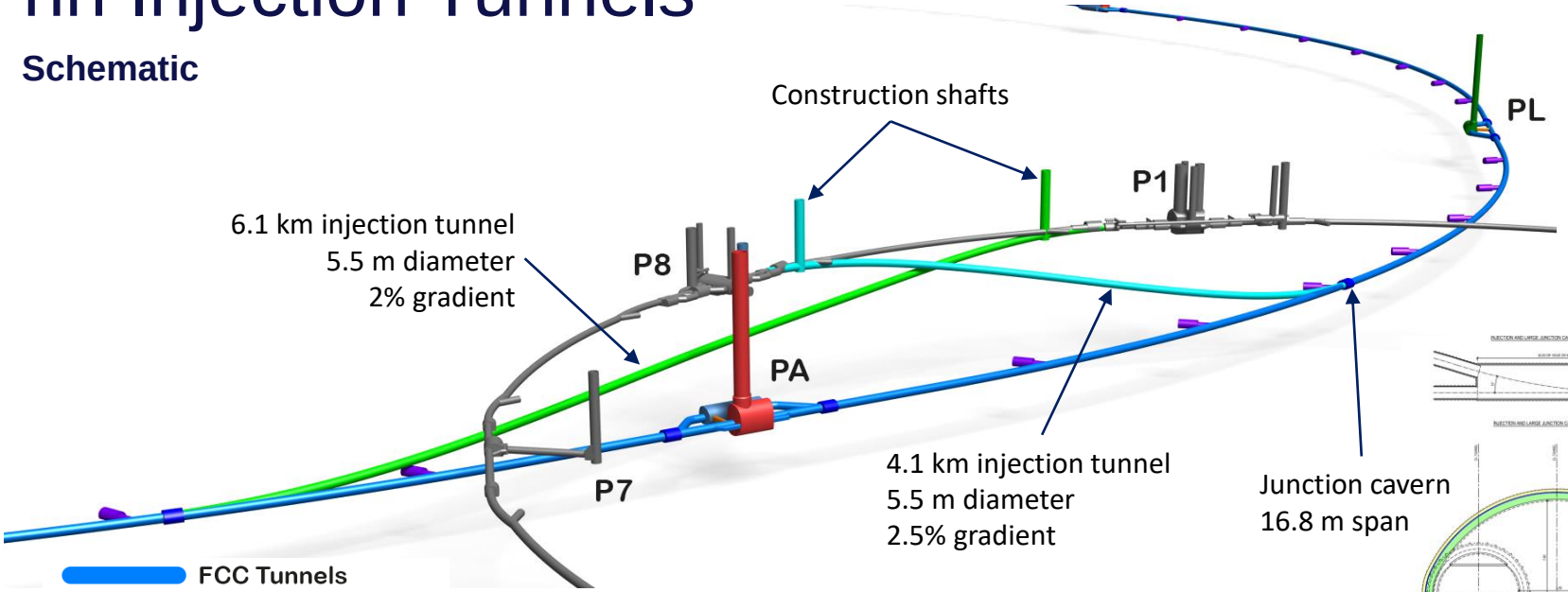


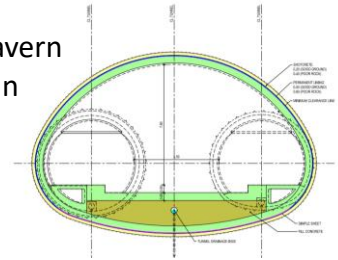
Changes

- Removal of points C, E, I and K
- Sectors increased to 11 km
- Point F inclined access replaced with displaced access shaft
- Klystron Galleries at Point H and L
- Point H & L tunnel widening to 6.0m diameter
- 4 technical sites (reduced from 8)
- Tunnel widening at points A & G

hh Injection Tunnels

Schematic



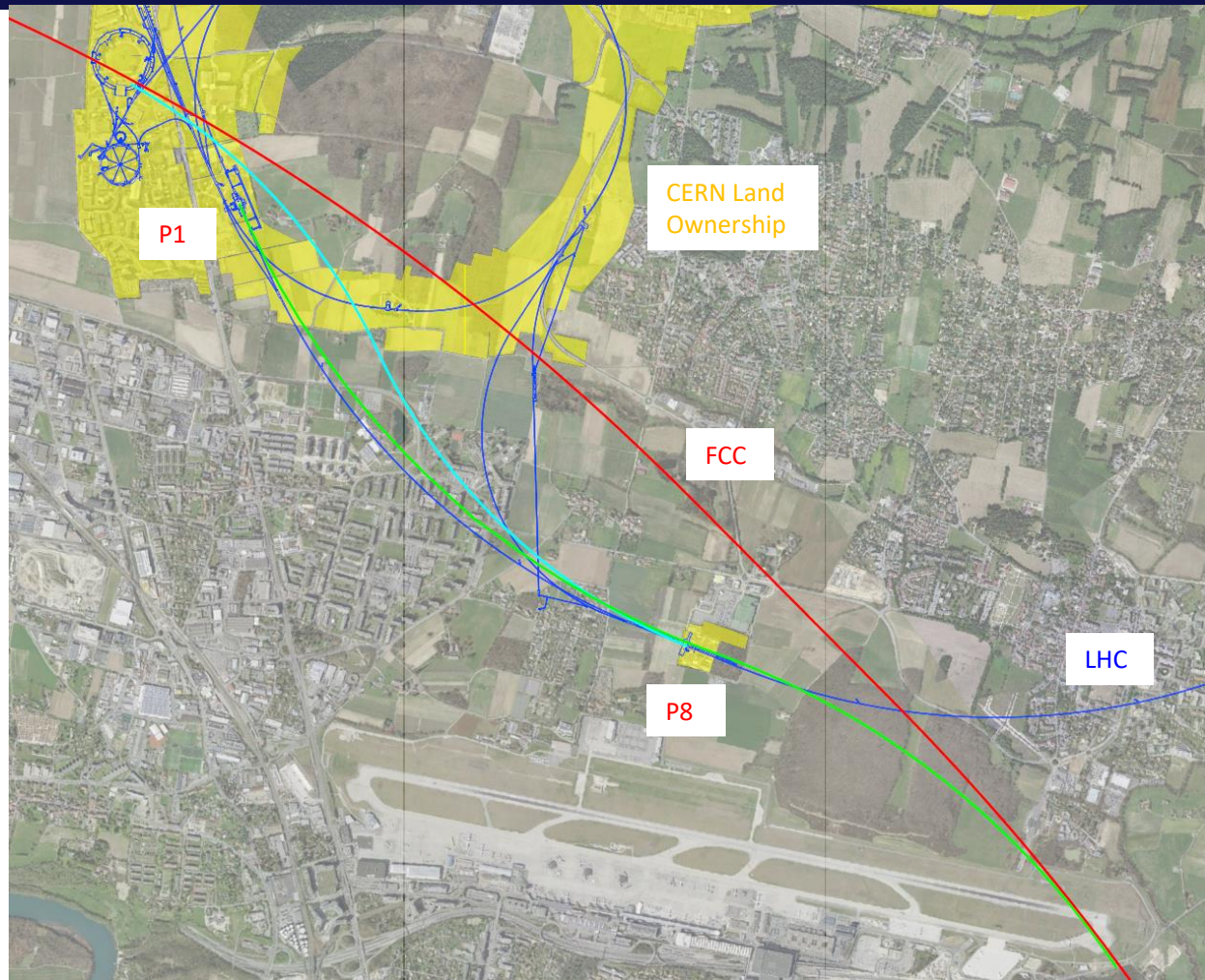


(For 12 Point FFC injection tunnels were 4.7 km and 7.1 km)

hh Injection Construction Shafts

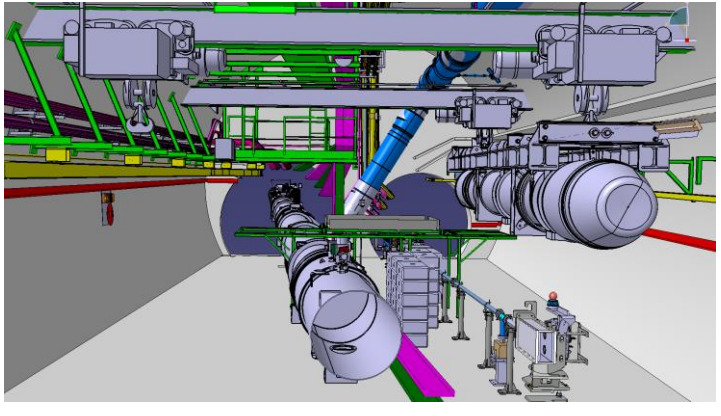
Temporary shafts required to construct injection tunnels

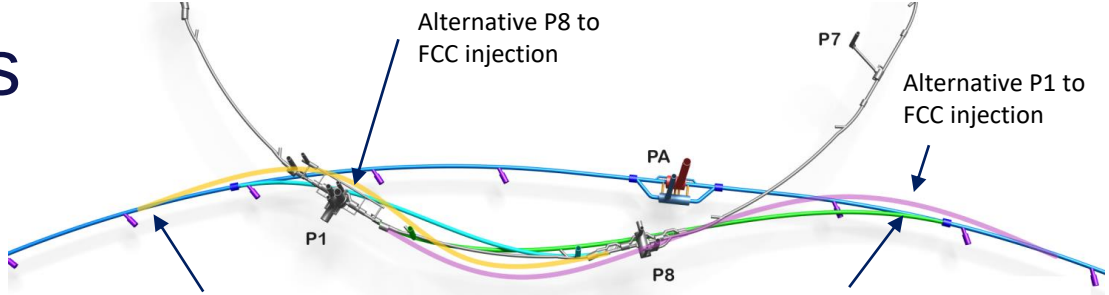
Possible to locate at existing LHC Points 1 and 8.



hh Injection Tunnels

Beam junction



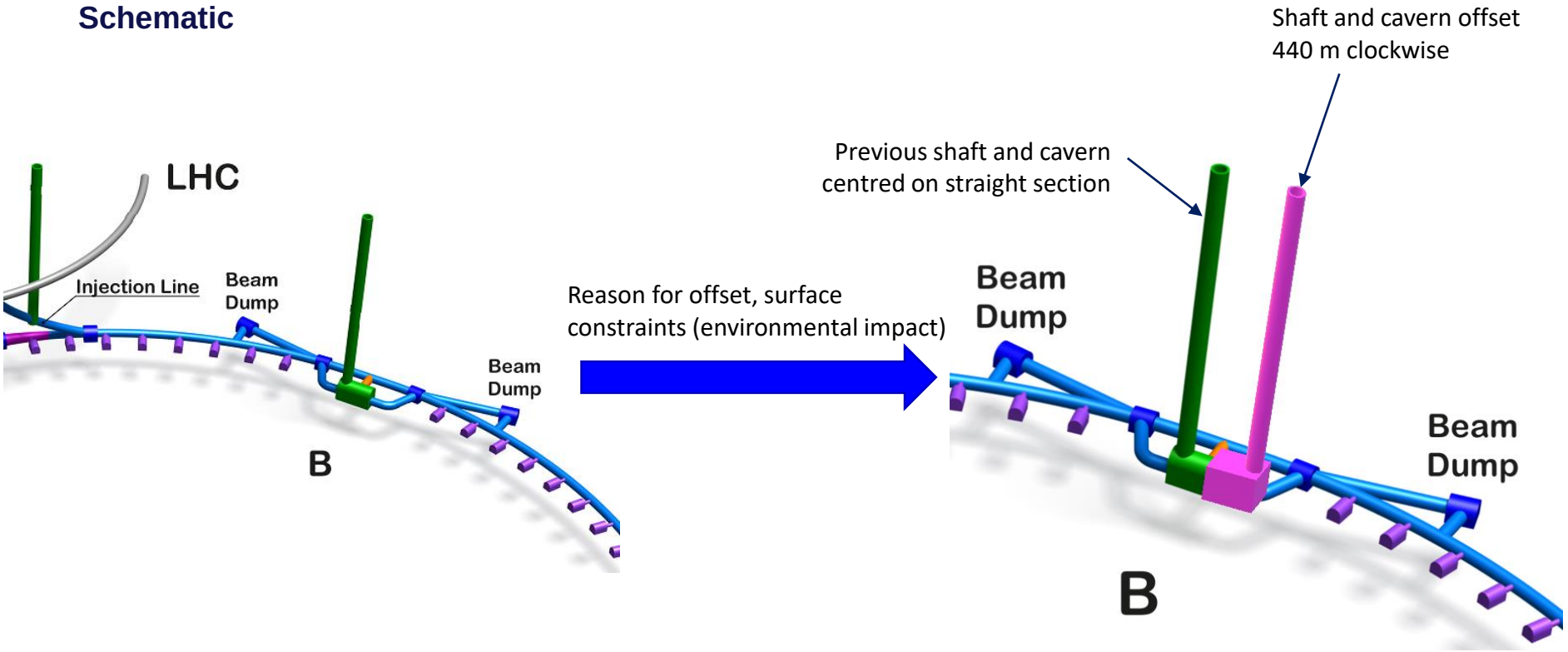


Junction with FCC on the outside of ring, to avoid clash with the transport corridor

If junction on inside, crane and bridge required to continue main FCC transport. Transport corridor will not be continuous around full ring.

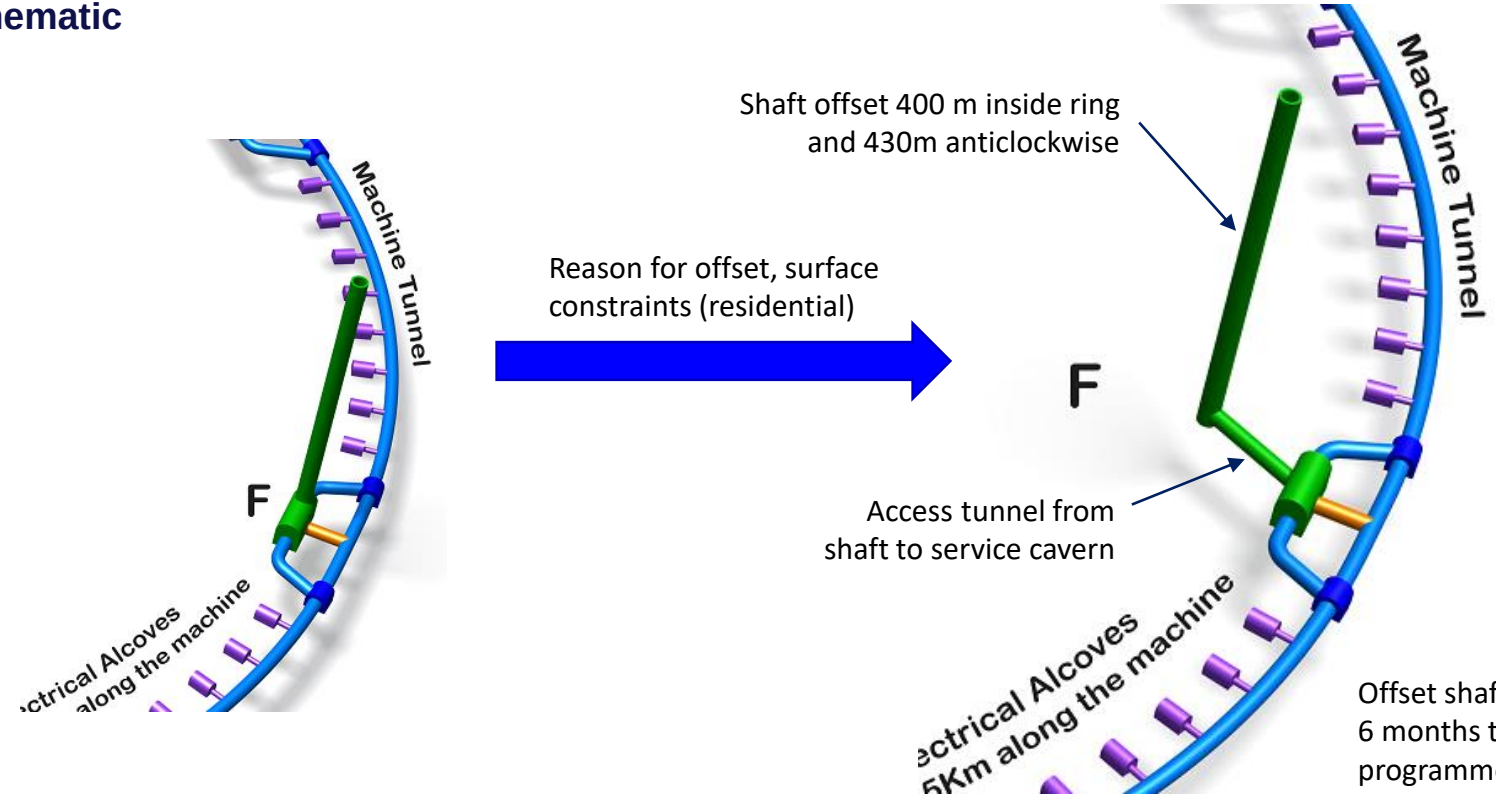
Offset Shaft - Point B

Schematic



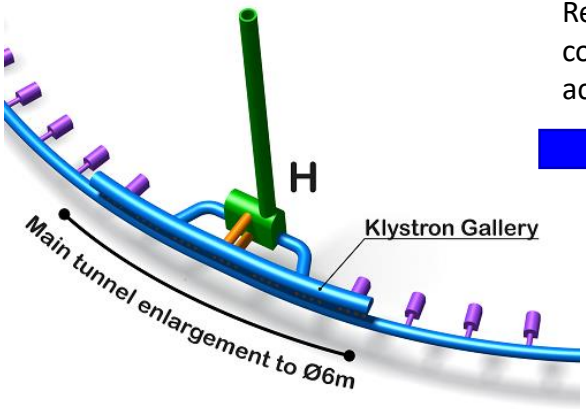
Offset Shaft - Point F

Schematic

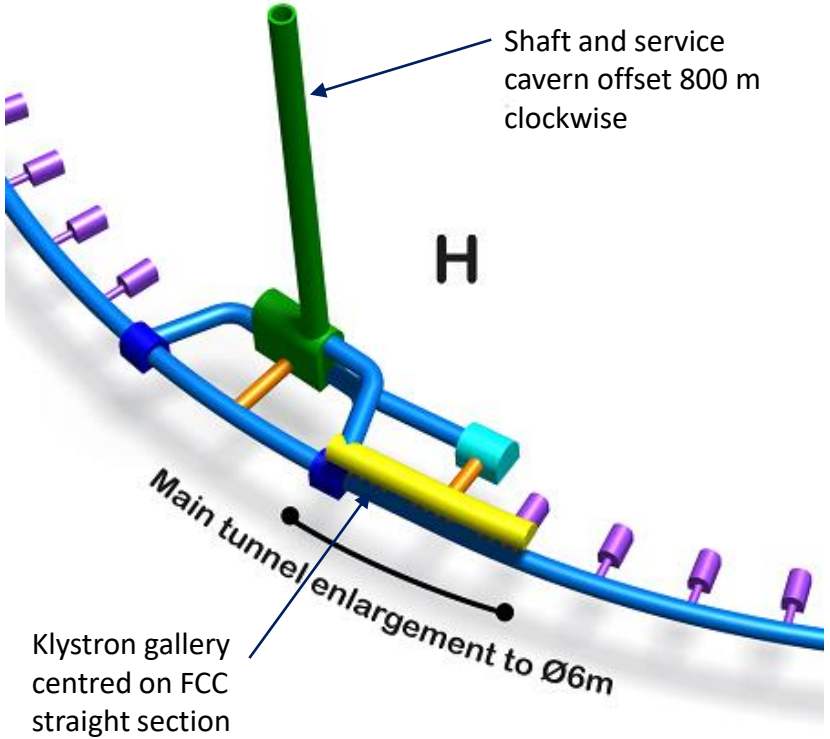


Offset shaft adds approx. 6 months to construction programme

Offset Shaft - Point H



Reason for offset, surface constraints (residential) and access requirements



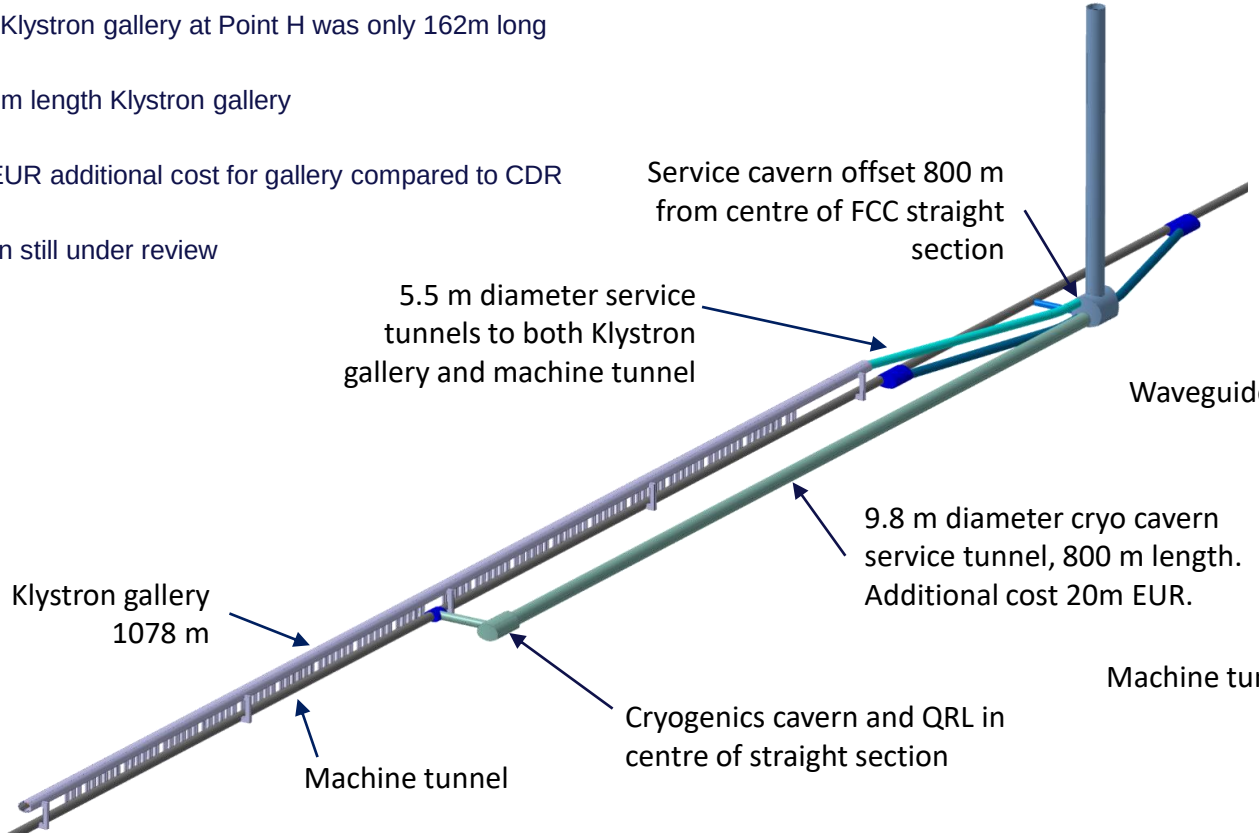
Klystron Gallery - Point H

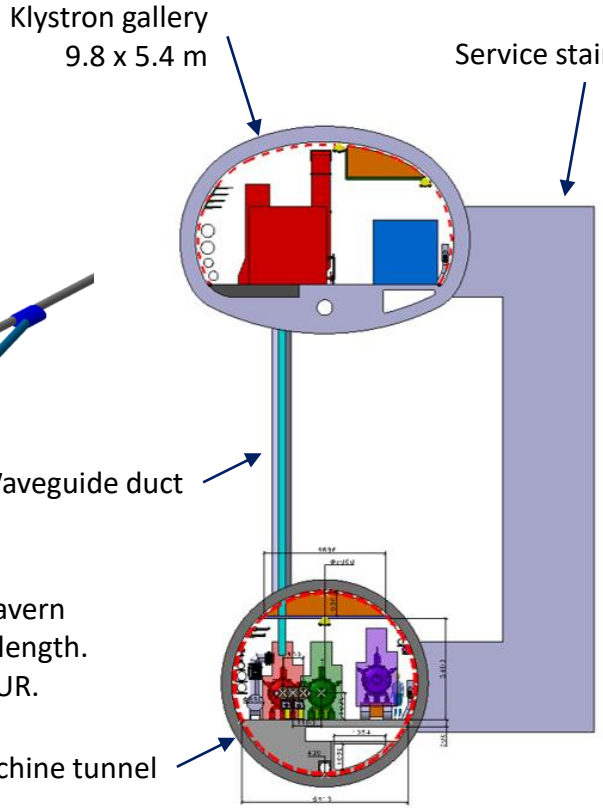
CDR Klystron gallery at Point H was only 162m long

1078 m length Klystron gallery

17MEUR additional cost for gallery compared to CDR

Option still under review

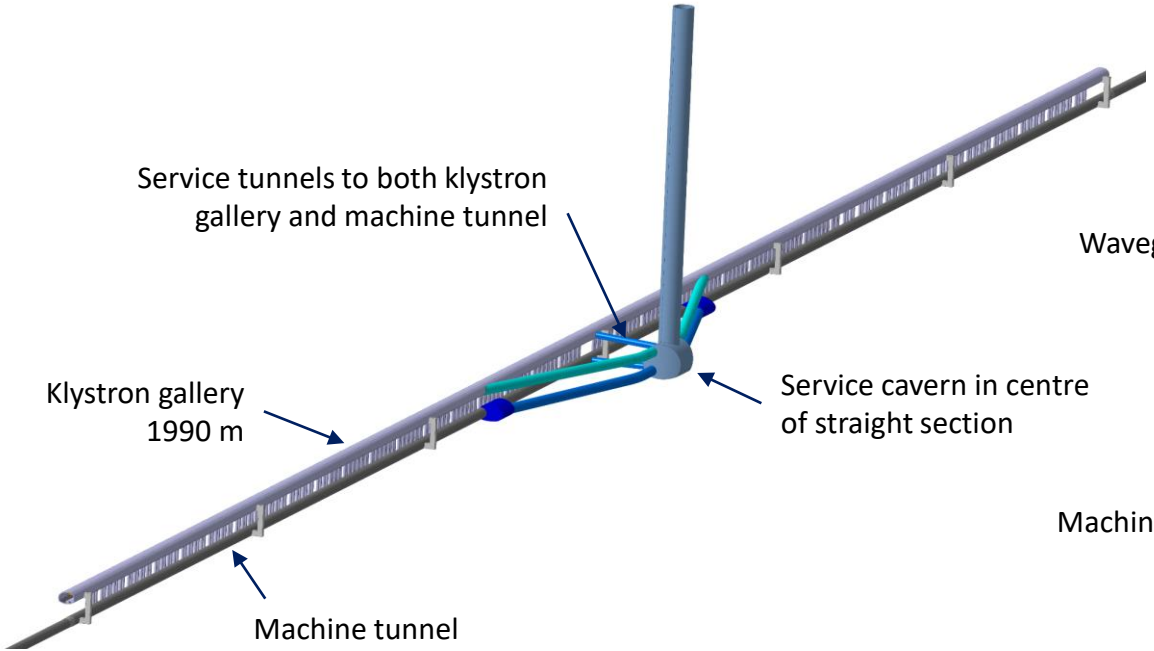


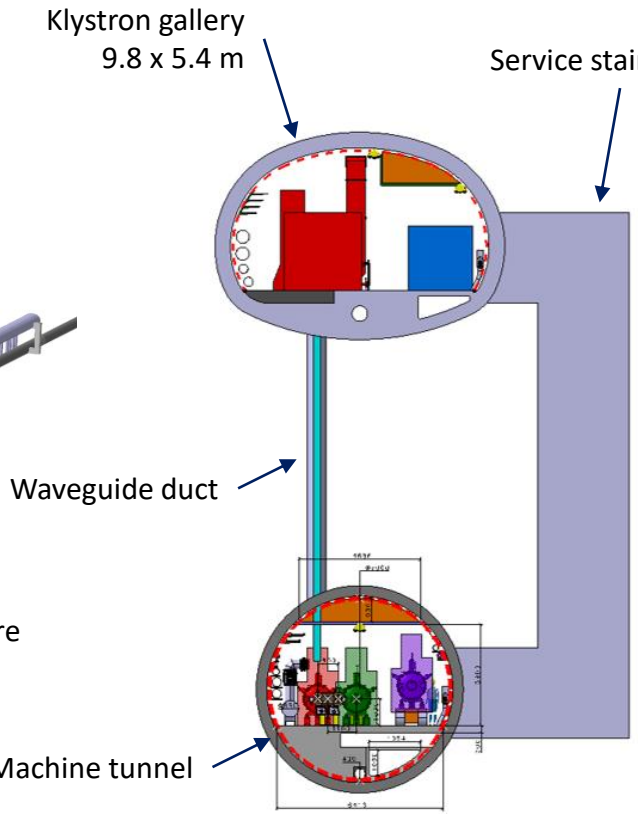


Klystron Gallery - Point L

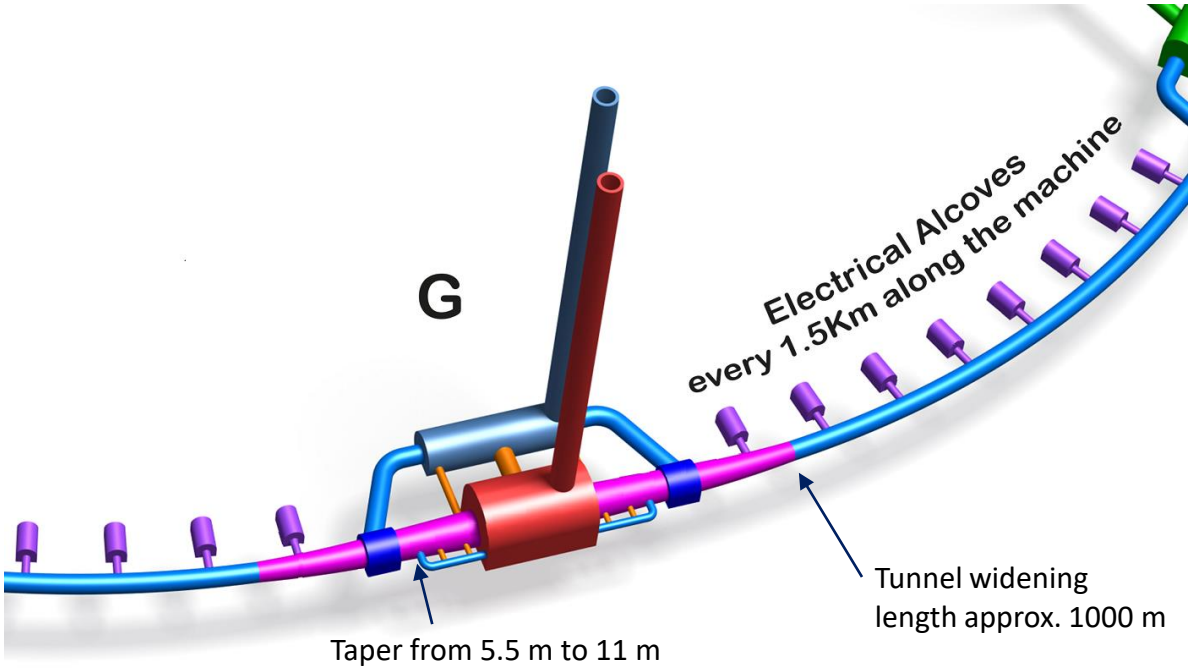
1990 m length Klystron gallery

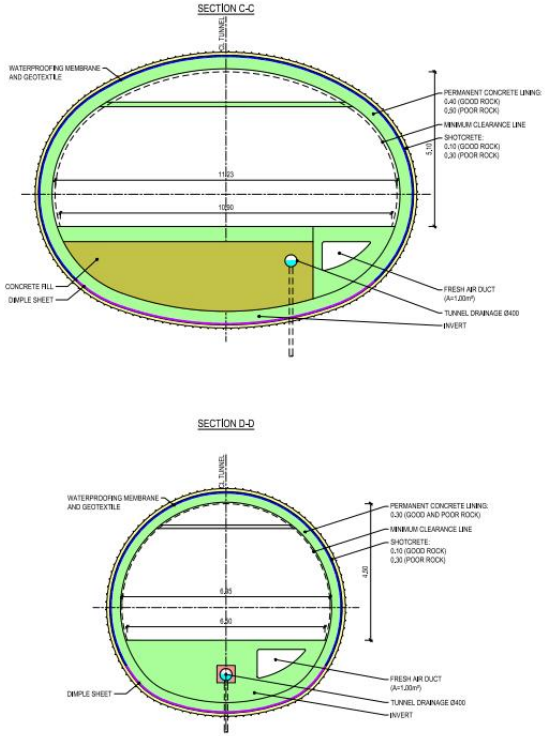
30m EUR additional cost from CDR



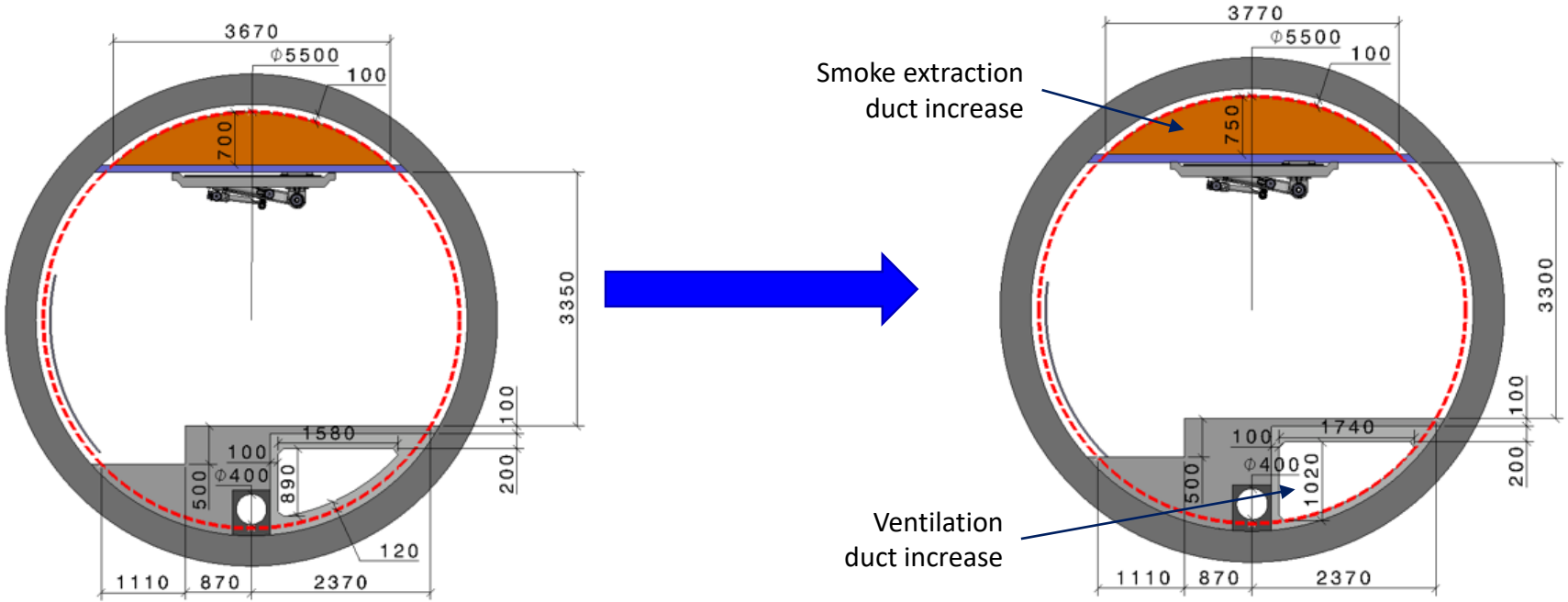


Tunnel Widening - Point A & G

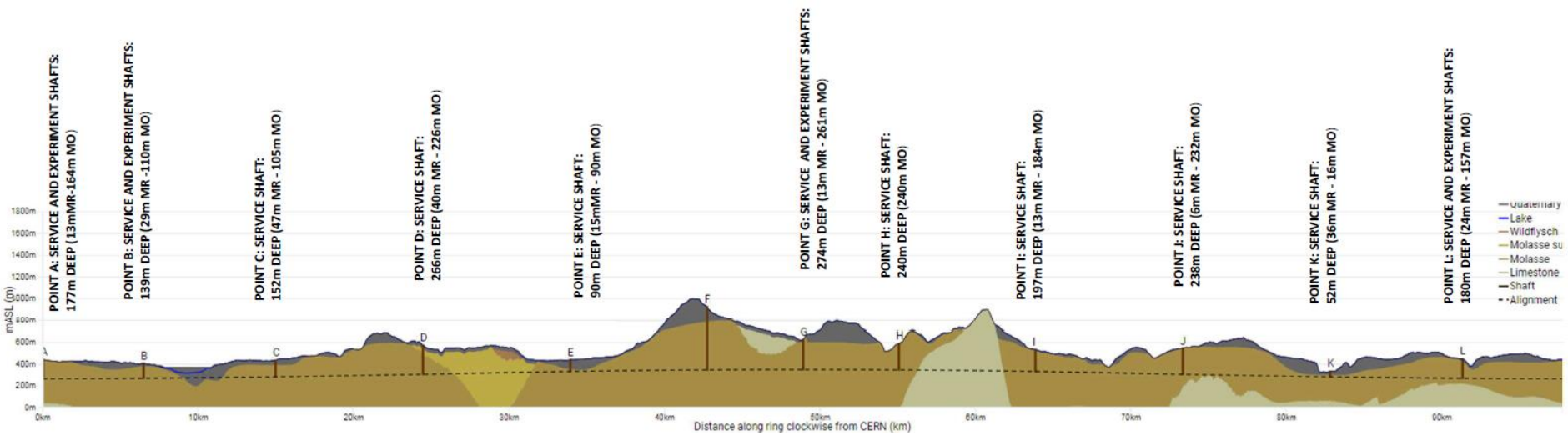




Tunnel Cross Section (Typical 5.5 m diameter)



CDR 12 Site FCC Long Section



Shaft depths:

Total shaft depth = 2005 m

A: 177 m

B: 139 m

C: 152 m

D: 266 m

E: 90 m

F: NA (Inclined tunnel)

G: 274 m

H: 240 m

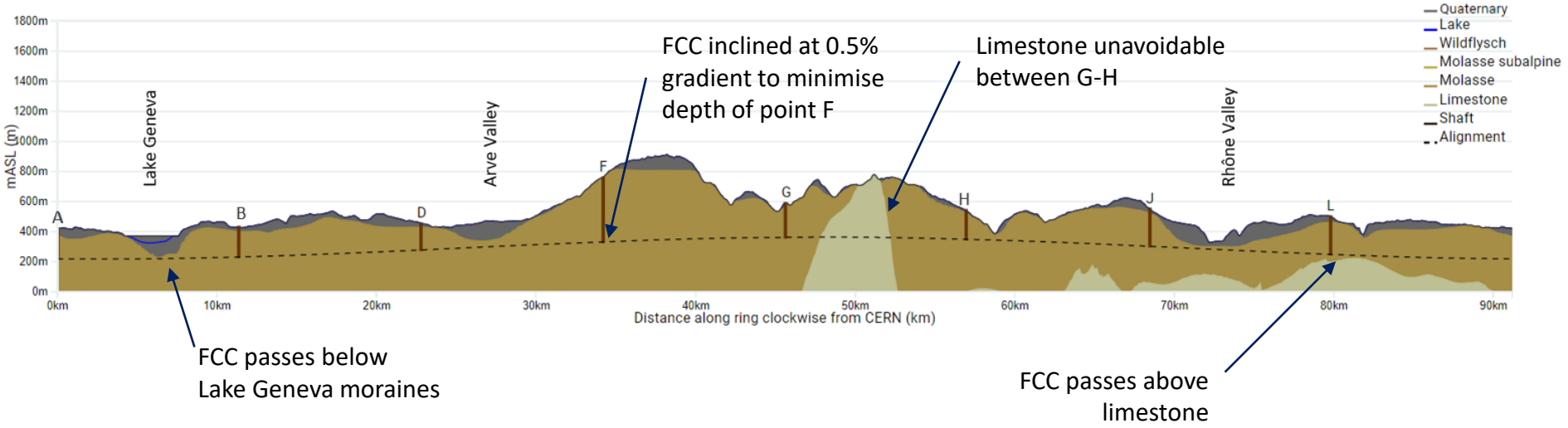
I: 197 m

J: 238 m

K: 52 m

L: 180 m

FCC Long Section – PA31-1.0



Shaft depths:

Total shaft depth = 1849 m

A: 202 m B: 200 m D: 177 m F: 399 m G: 228 m H: 139 m J: 251 m L: 253 m

Conclusions

- Baseline FCC designs for underground structures to be frozen by end of 2022.

This will allow our consultants to do an updated cost/schedule estimate ahead of mid term review.

- SI consultants commence specifications July 2022

- SI contractors to start on site commence Q2 2024

Thank you
for your attention.