



# Civil engineering for LHeC and FCC-eh

Workshop on the LHeC, FCC-eh and PERLE

25 October 2019

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# Agenda

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Positions and layout configurations

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Geology

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Underground structures

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Cost estimates

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Surface sites

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Spoil management

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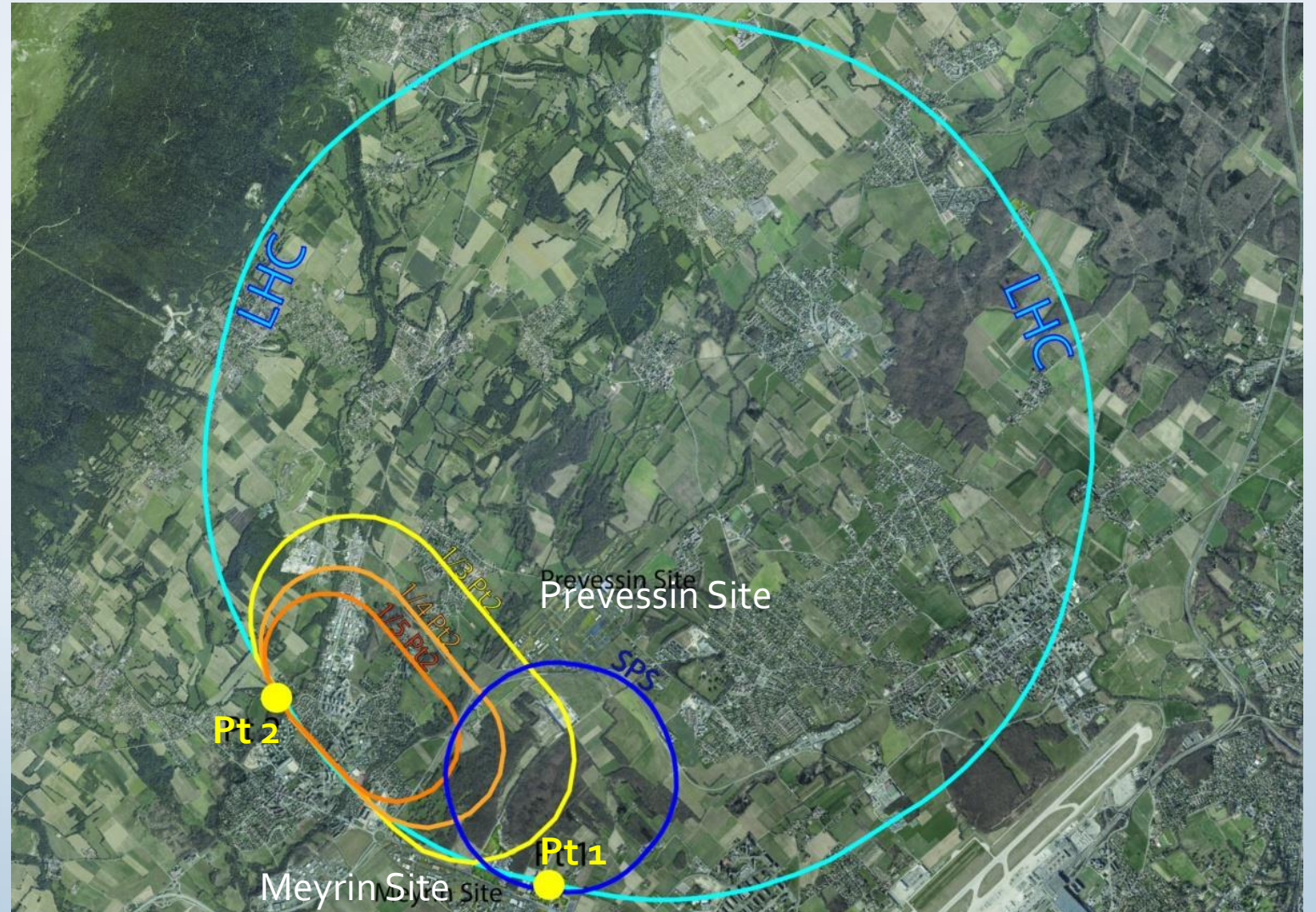
Future studies

# Alignment and positioning of LHeC

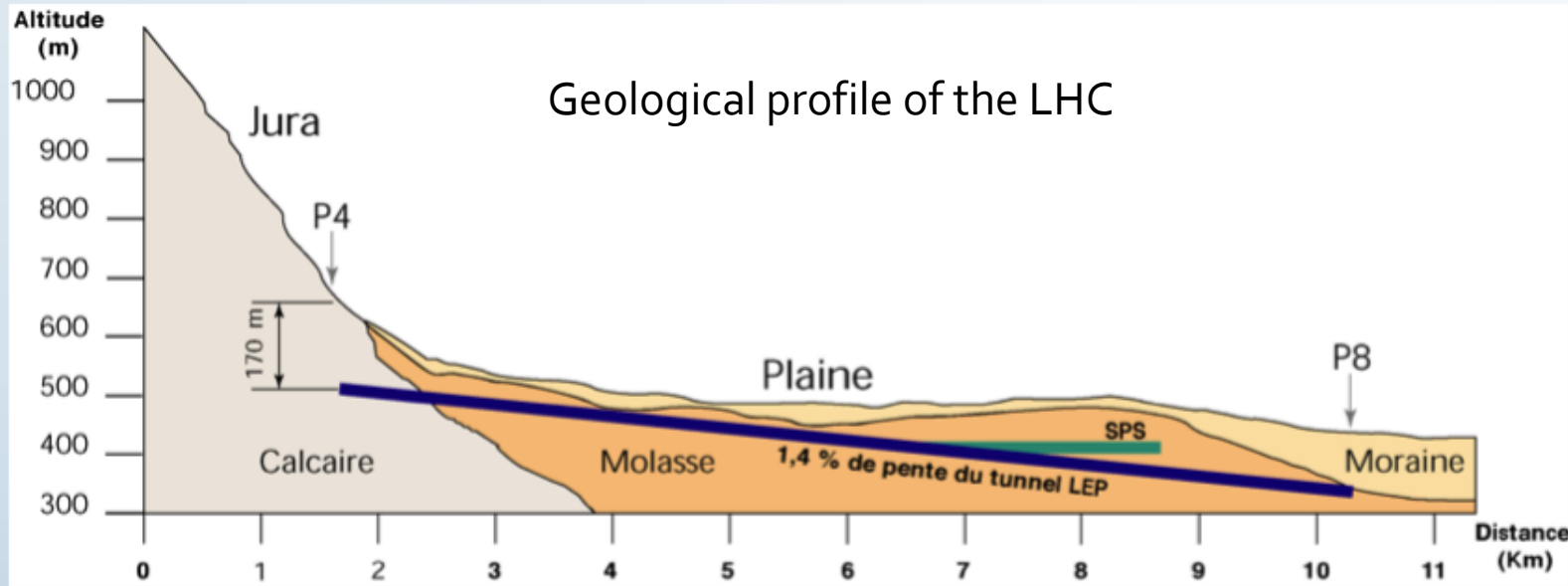
Point 2 preferred as it allows infrastructure to be located on CERN land.

The LHeC machine could be scaled down to:

- 1/5 LHC
- 1/4 LHC
- 1/3 LHC



# Geology

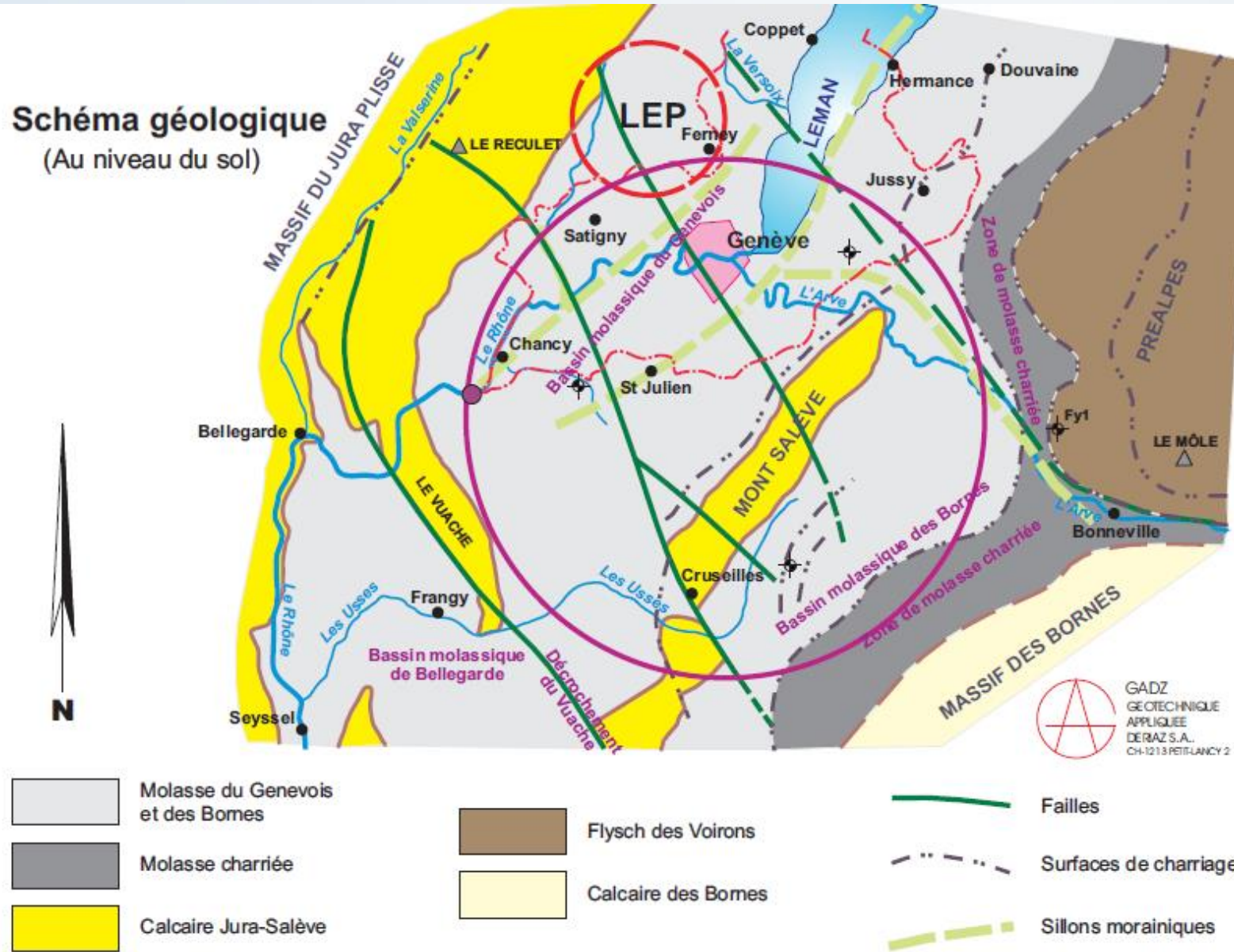


Rock type	Average $\sigma_c$ (Mpa)
Sandstone	10.6
<i>weak</i>	
<i>strong</i>	22.8
<i>Very strong</i>	48.4
Sandy marl	13.4
Marl	5.7

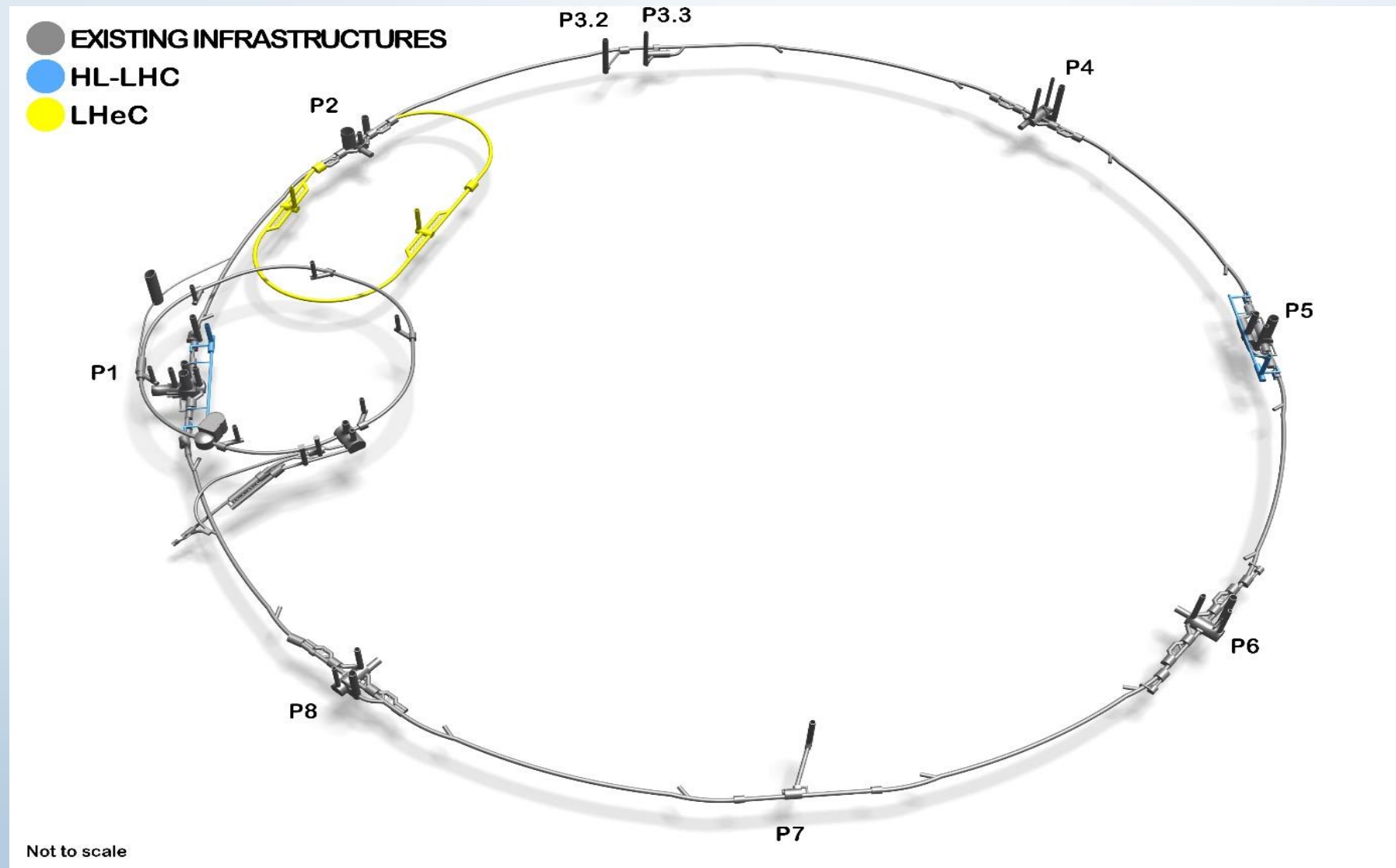
- Well understood geology and good record data from LEP and LHC in CERN region
- LHeC tunnels and caverns in molasse – dry and stable rock, suitable for tunneling
- Shafts excavated in moraines and molasse

# Geology

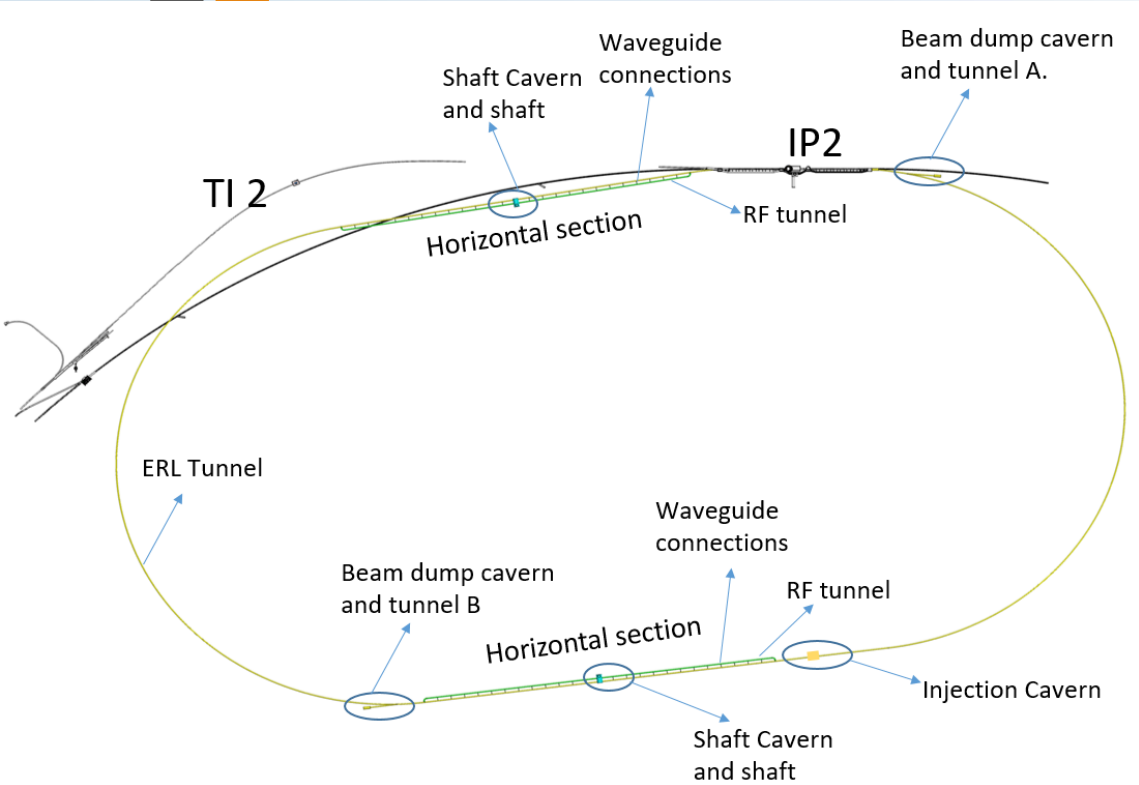
Schéma géologique  
(Au niveau du sol)



# 3D schematic of underground infrastructure



# LHeC Underground structures

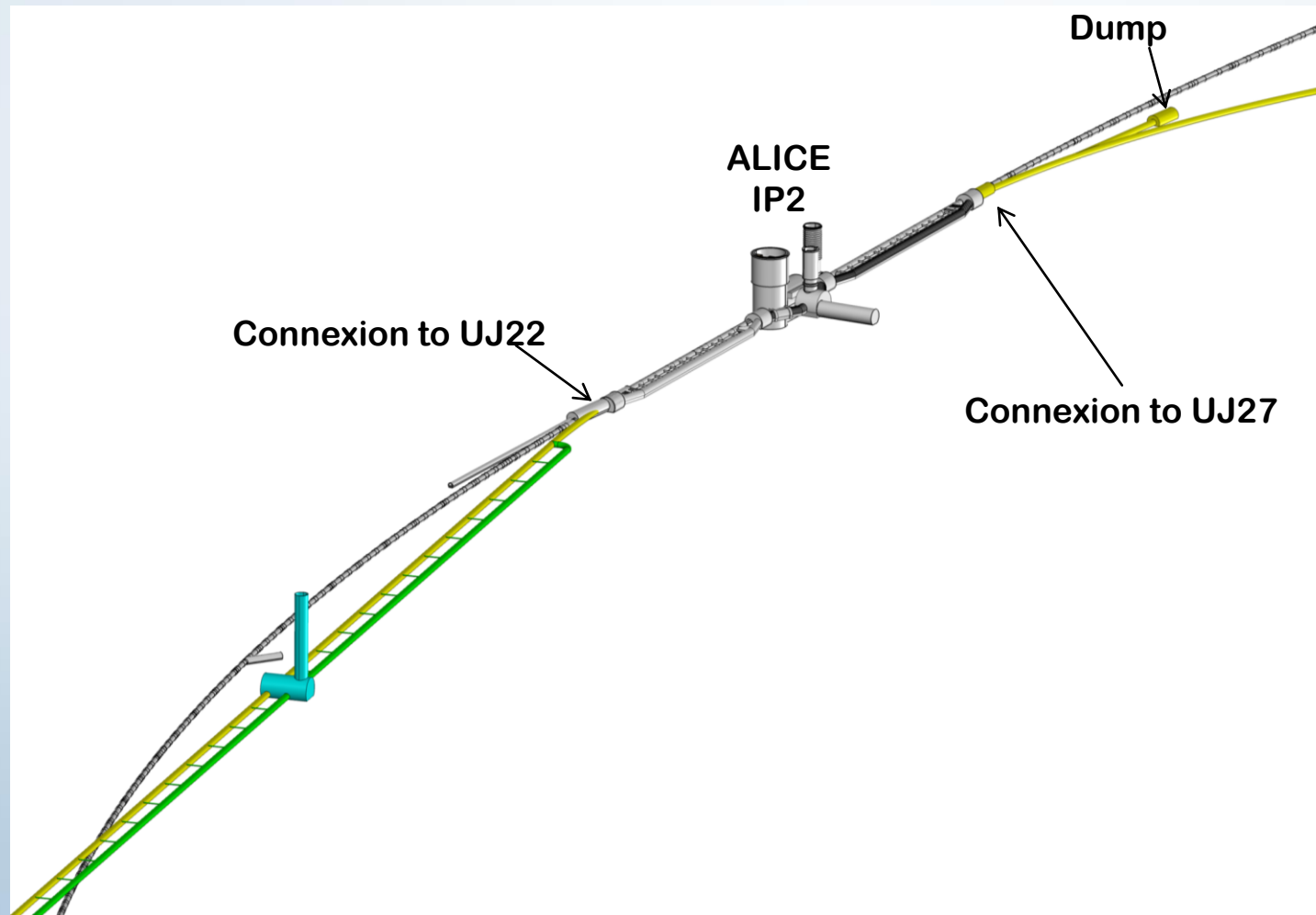


Structures for 1/3 LHC option	Quantities	Length	Span / Diameter
Machine tunnels	-	9091m	5.5m ID
Service caverns	2	50m	25m
Service shafts	2	80m	9m ID
Injection cavern	1	50m	25m
Dump cavern	1	90m	16.8m
RF Galleries	2	1070m	5.5m
Waveguide connections	50	10m	1m ID
Connection Tunnels	4	10m	3m ID
Junction Caverns	3	20m	16.8m

Structures for 1/5 LHC option	Quantities	Length	Span / Diameter
Machine tunnels	-	5400m	5.5m ID
Service caverns	2	50m	25m
Service shafts	2	80m	9m ID
Injection cavern	1	50m	25m
Dump cavern	1	90m	16.8m
RF Galleries	2	830m	5.5m
Waveguide connections	40	10m	1m ID
Connection Tunnels	4	10m	3m ID
Junction Caverns	3	20m	16.8m

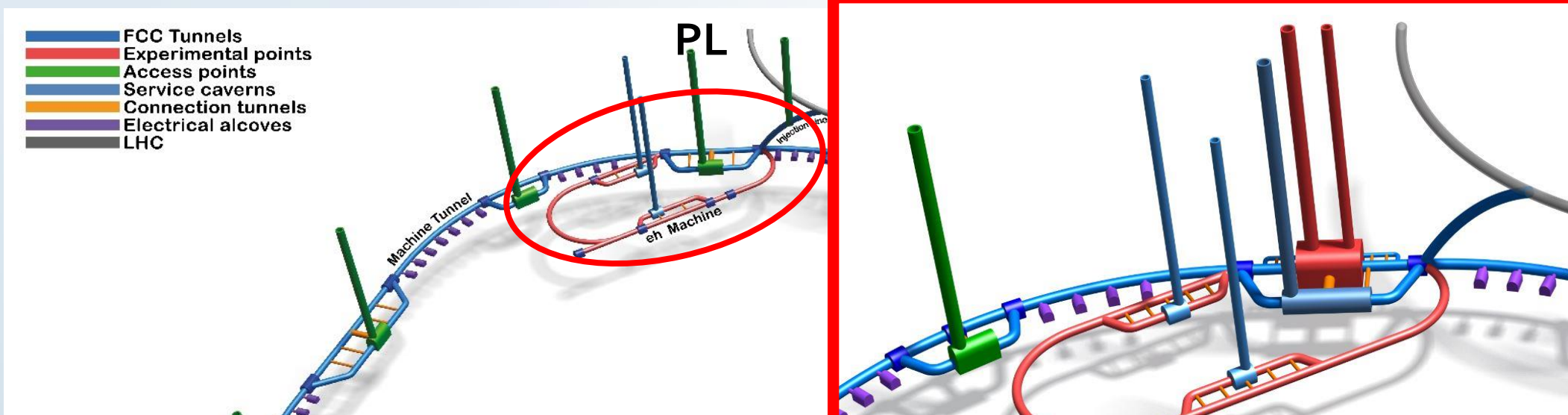
# LHeC Underground structures

Modifications to existing LHC infrastructure: UJ22 and UJ27 caverns needs to be enlarged to ensure connection with eh tunnel

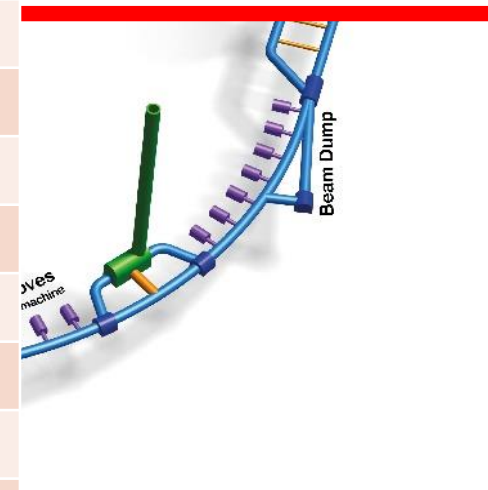




# FCC-eh Underground structures and layout configuration



Structures	Quantities	Length	Span / Diameter
Machine tunnels	-	9091m	5.5m ID
Service caverns	2	50m	25m
Service shafts	2	175m	9m ID
Injection cavern	1	50m	25m
Dump cavern	1	90m	16.8m
RF Galleries	2	1070m	5.5m
Waveguide connections	50	10m	1m ID
Connection Tunnels	4	10m	3m ID
Junction Caverns	5	20m	16.8m



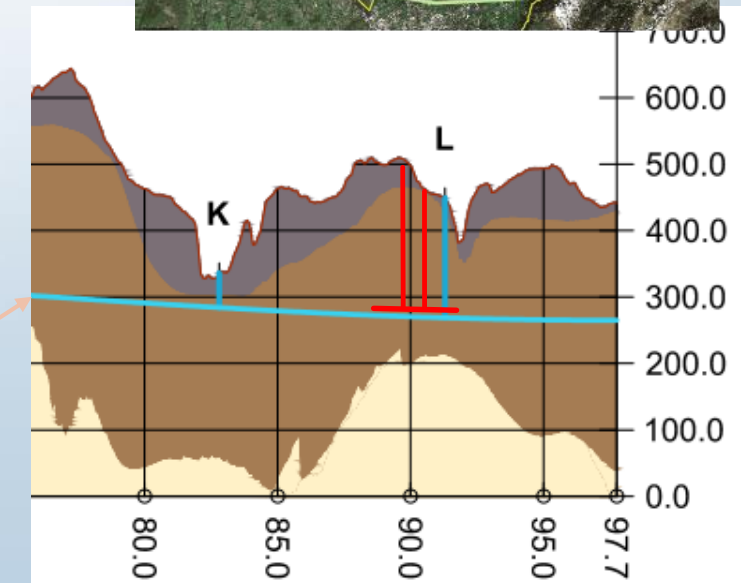
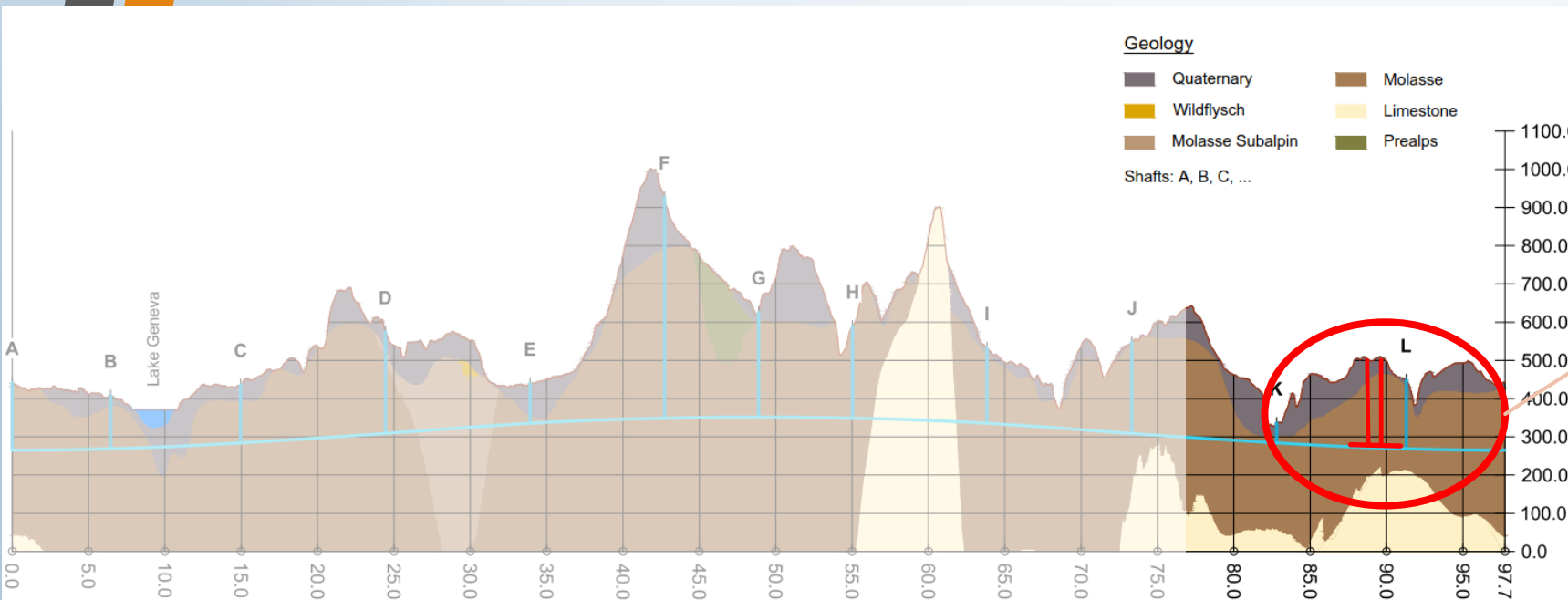
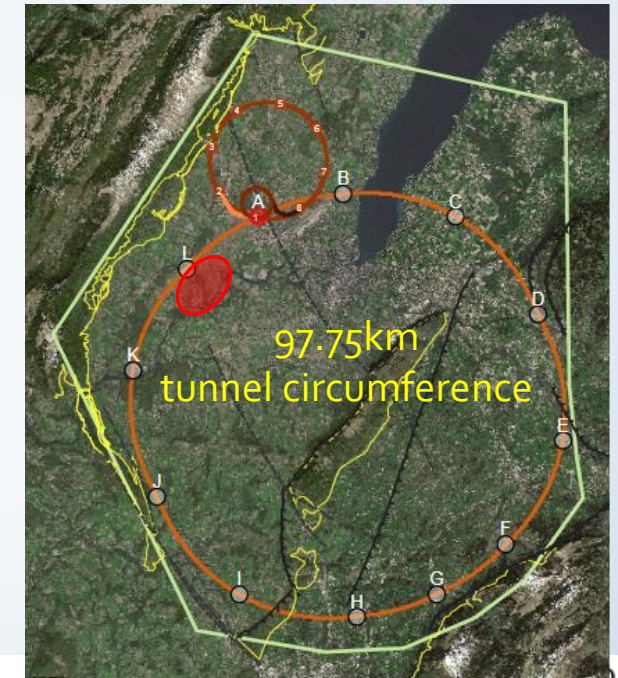
# FCC-eh: tunnel position and geological profile

FCC-eh placed at experimental point L provides the following benefits:

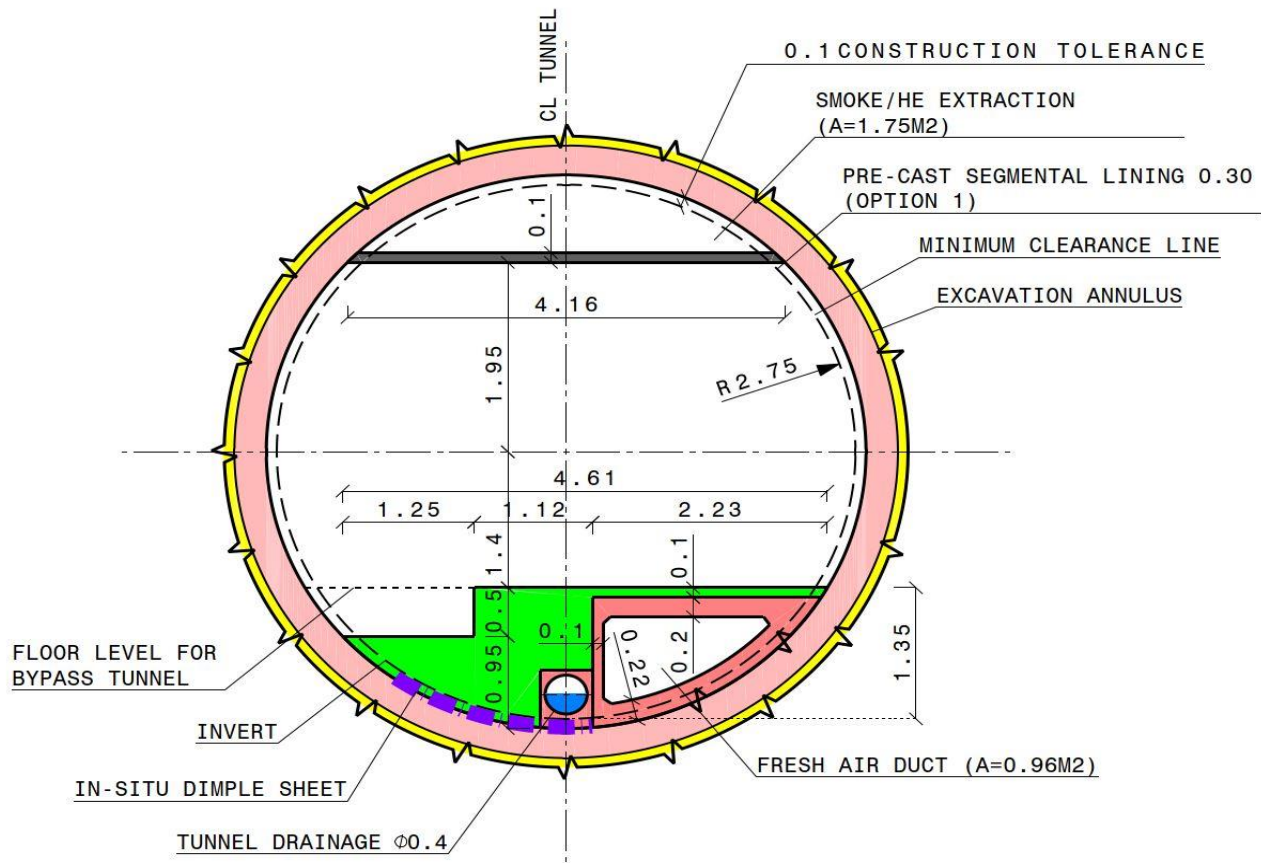
- Low geological risk compared to other locations, anticipated tunnelling in molasse only.
- Close to current CERN site.
- FCC ring relatively shallow at this point, therefore shallower shafts

## Remaining issues to be studied:

- Located inside the FCC ring so integration with other structures to be studied.
- Depth below Allondon to be evaluated

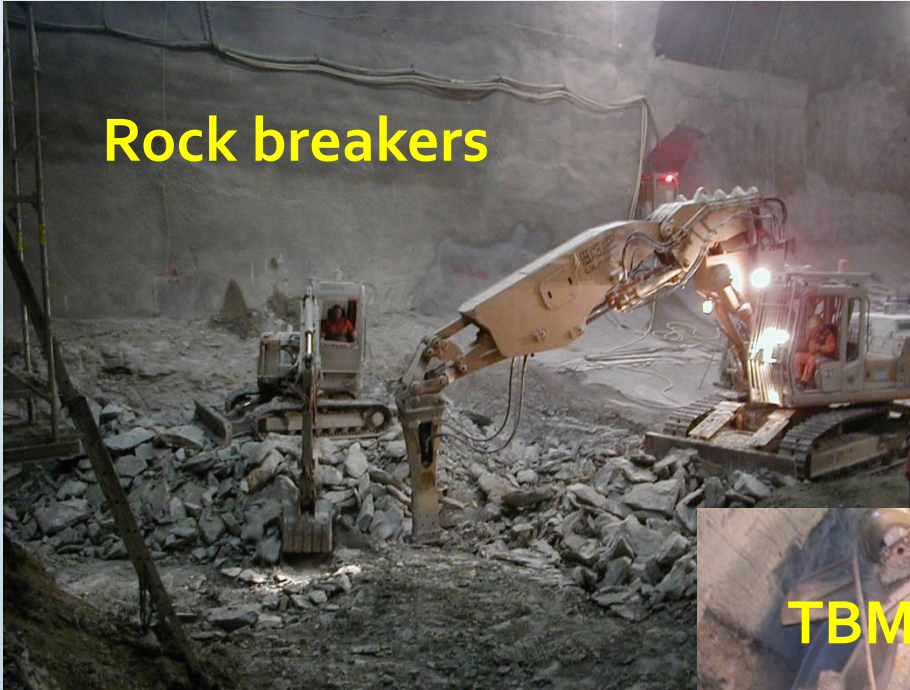






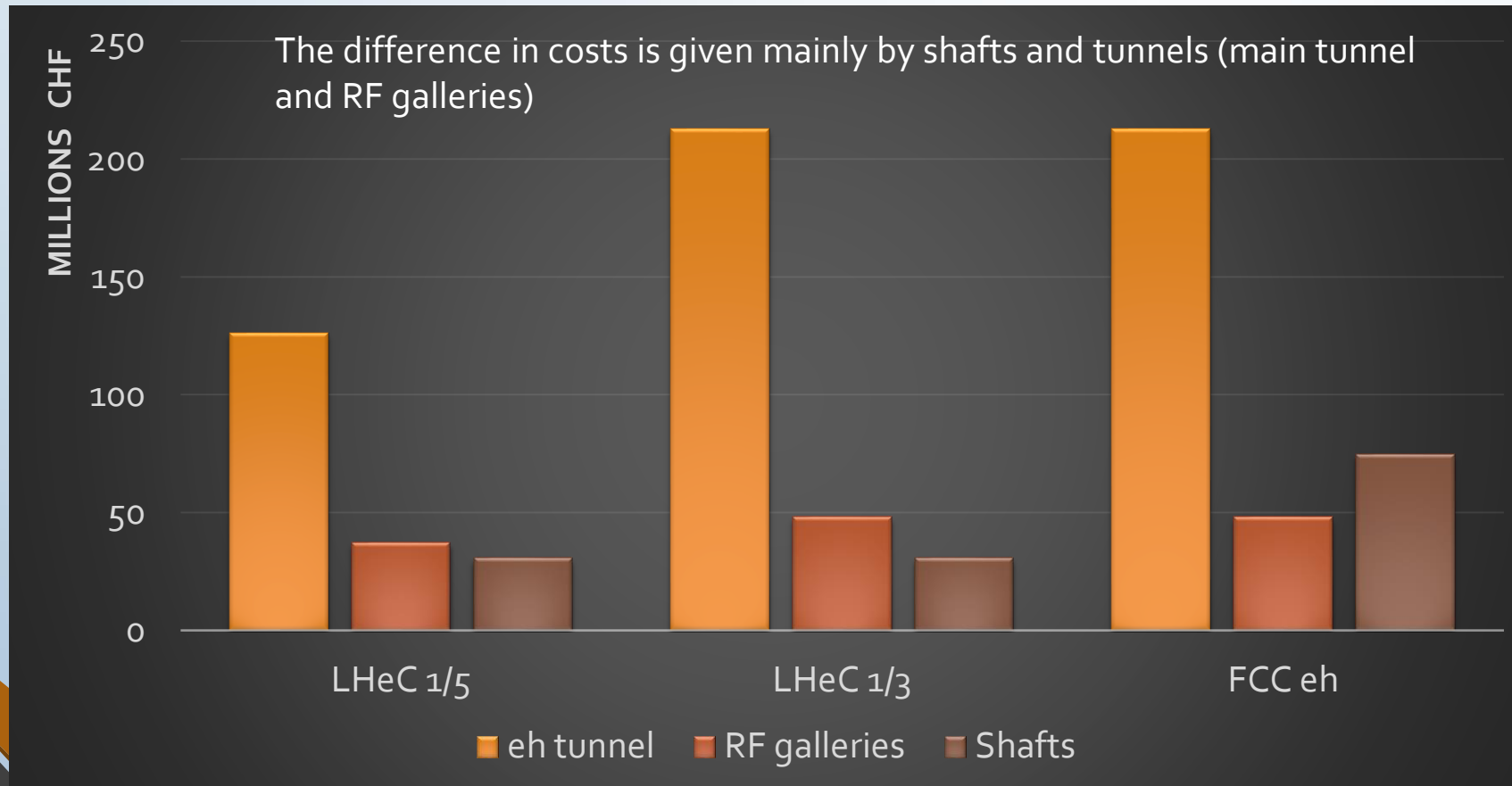
# Typical tunnel cross section

# Construction techniques



# Cost estimates for civil engineering

LHeC 1/5 option	LHeC 1/3 option	FCC-eh
290 MCHF	390 MCHF	430 MCHF



The unit costs and percentages are consistent with FCC and CLIC unit prices.

The cost estimates include:

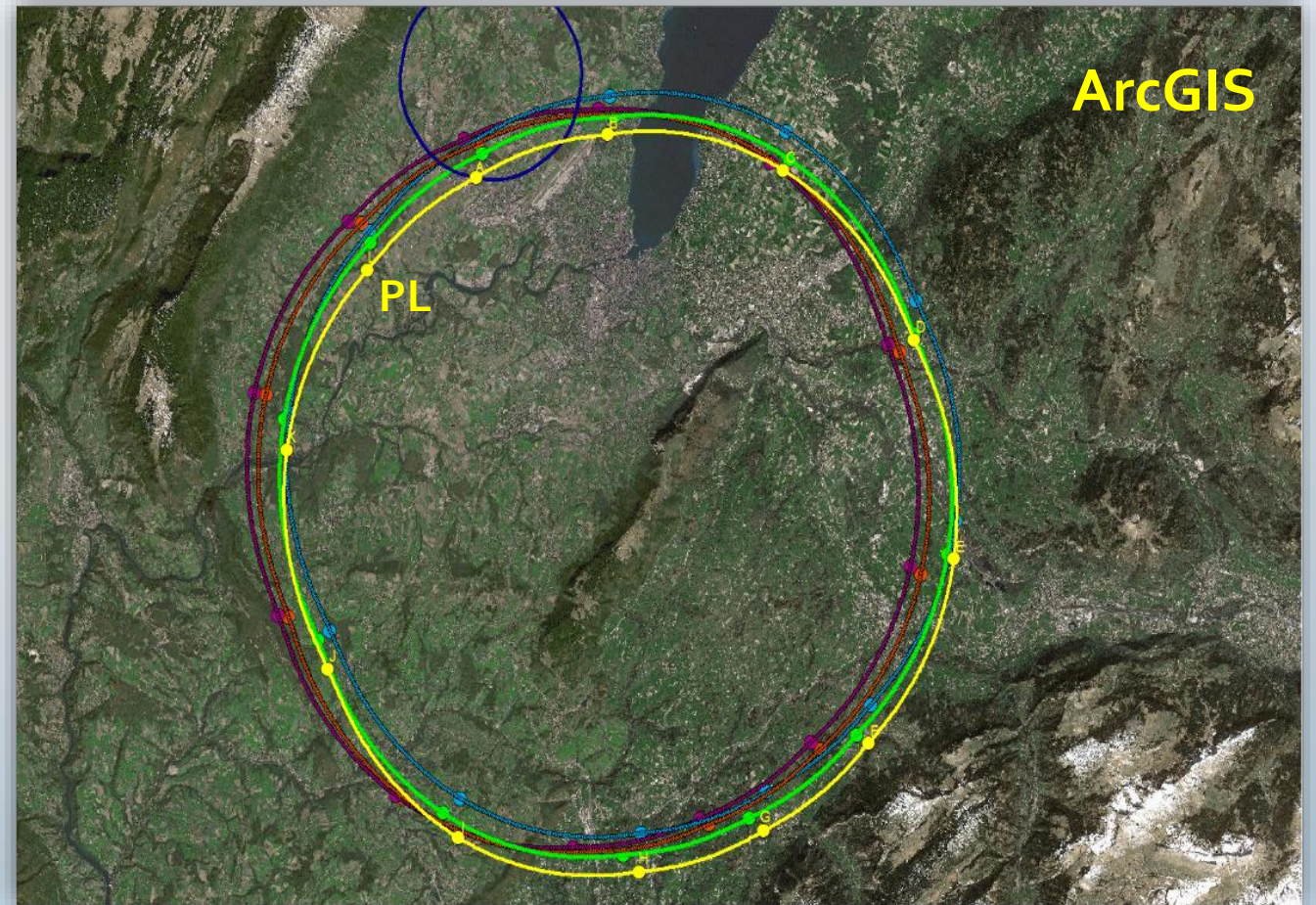
- Site investigations: **2%**
- Preliminary design, tender documents and project changes: **12%**
- Contractor's profit: **3%**

Cost of surface sites not included at this stage.

*Note: Cost accuracy for feasibility stage is  $\pm 30\%$*

# FCC: Ongoing footprint exploration

A further round of alignment optimisation following input from **surface sites review** with French and Swiss authorities



# FCC pre-construction schedule

CDR submitted to ESPP



European Strategy Update 2020



FCC pre-construction schedule	2019				2020				2021				2022				2023				2024				2025				2026				2027				2028			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
LHC Operation Period	LS2				LHC run 3				LS3				LHC run 4																											
CERN feasibility	Alignment optimisation																																							
Site Investigation					Feasibility SI (geophysics & walkover surveys)				Principal SI - Phase 1				Principal SI - Phase 2				Principal SI - Phase 3 Additional SI as necessary																							
Consultant Contracts					Contract and tender strategy				Market Survey				Tender and Award				Preliminary design				Tender design				Construction Design															
Construction Contracts																									Market Survey				Tender and Award											
EIA and permitting documents	Environmental Impact Assessment and permitting documentation																																							

★ Start of Construction

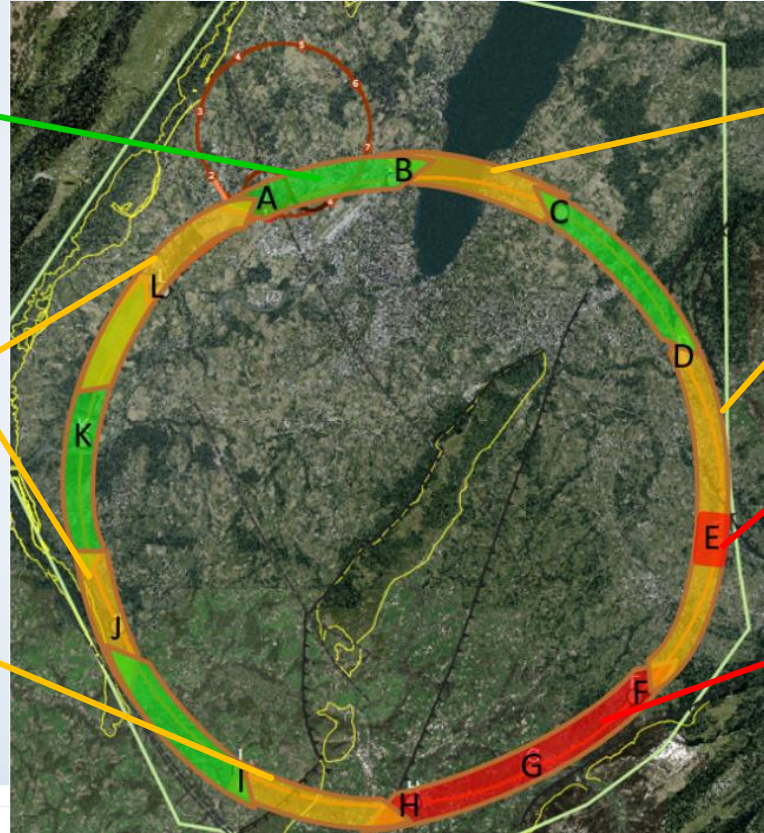


# Geological uncertainty

- Information near to CERN is strong due to previous experience on LEP/LHC.
- Multiple deep boreholes in the area.

- **Alignment close to limestone rockhead.**
- **The exact location and angle of the limestone/molasse interface undefined.**

- Limestone formation known, but characteristics and locations of karsts unknown.

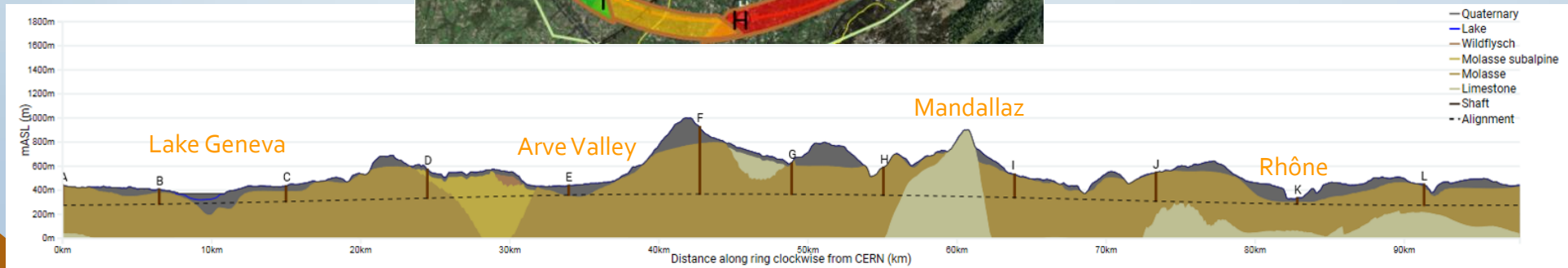


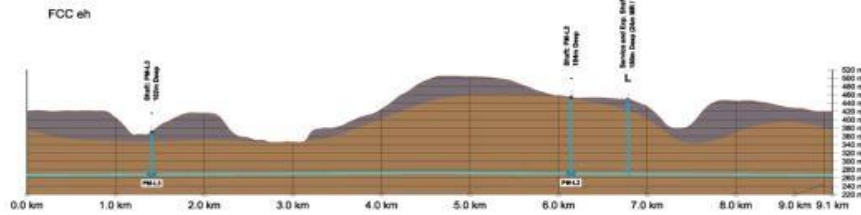
- Seismic and borehole information for lake crossing from proposed road tunnel, but layered nature of lake bed leads to uncertainty.

- Location of the interface between molasse and molasse subalpine not certain, tunnel alignment in proximity

- Moraine/molasse interface not certain, cavern close to interface.
- Lack of deep boreholes in area.

- No deep borehole information available in the area.
- Complex faulted region.
- Molasse/limestone interface uncertain.

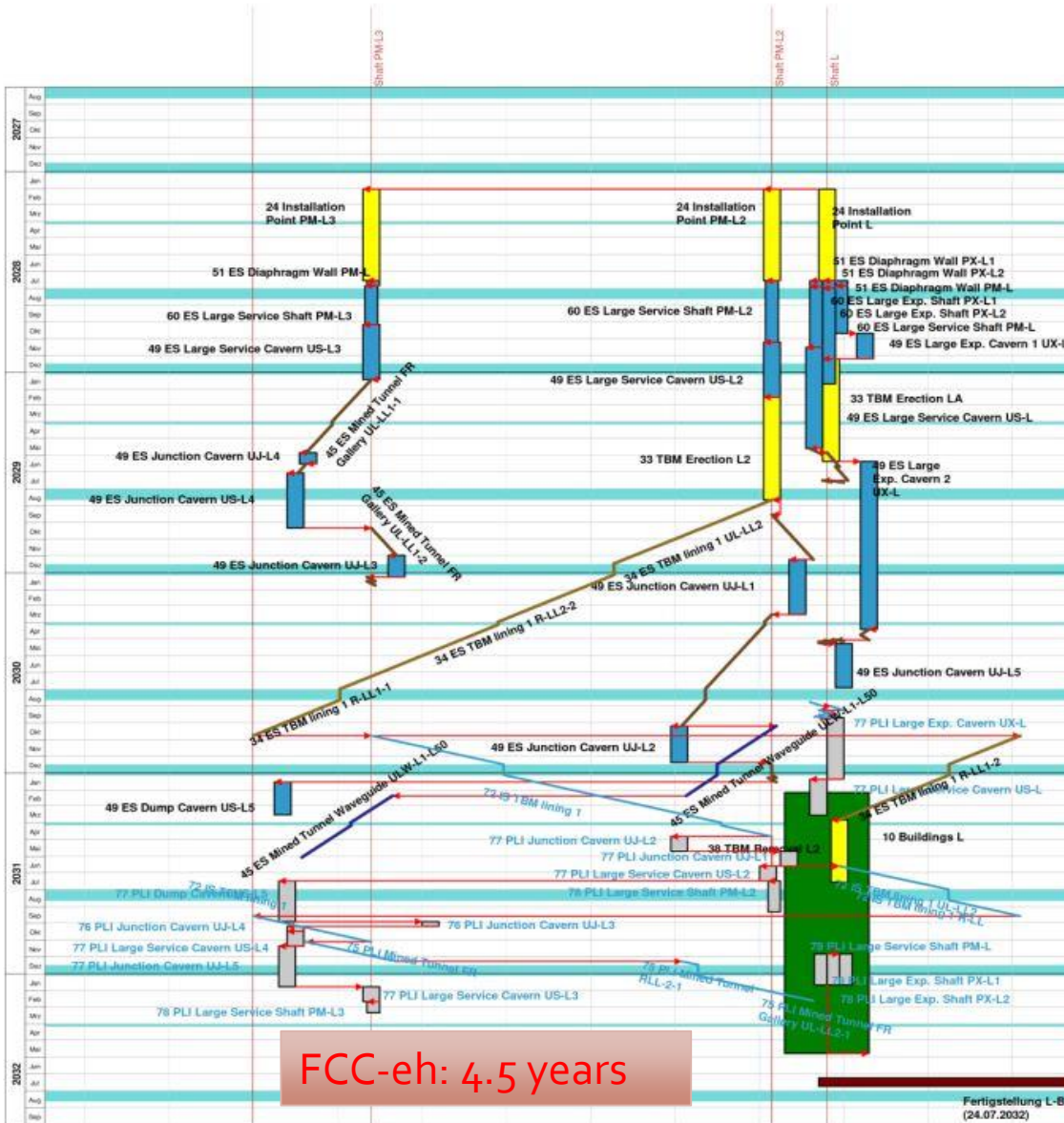




# FCC-eh construction schedule

## FCC-eh Schedule Considerations:

- The eh Civil Engineering work is expected to be undertaken as part of the FCC construction
- This schedule is therefore based on the schedule produced for the FCC main tunnel.
- FCC overall CE schedule 6.5 years



### Legend

- Site installations including roads  
TBM installation underground  
Deinstallation TBM and installation for inner lining and structures
- Shaft and cavern excavation  
Junction caverns
- TBM tunnelling segmental lining
- Mined tunnels with primary support
- Inner lining and structures works  
Invert and inner lining where applicable (option 2 for TBM, mined tunnel)  
Inner structures for safe walkway
- Inner lining and structures in caverns  
Inner lining shaft, internal walls for lift devices
- Buildings, roads, parking spaces, etc.

# Spoil Management

- the total spoil volume of FCC-eh is **777,582 m<sup>3</sup>**
- Assumed bulking factor of 1.3

Extraction Site	Volume (m <sup>3</sup> )			
	Soft Ground	Limestone	Molasses	Total
Construction Shaft at LHC1	11,031	0	133,735	144,765
Construction Shaft at LHC2	0	0	202,589	202,589
Shafts at Point A	26,469	0	751'365	818,417
Shafts at Point B	35,161	0	285'899	361,643
Shaft at Point C	181,807	0	385,920	567,727
First Construction Tunnel at Point D	0	0	709,452	709,452
Shaft at Point D	15,992	8,806	668,961	693,760
Second Construction Tunnel at Point D	0	0	235,355	235,355
Shaft at Point E	6,528	0	174,792	181,320
Tunnel at Point F	0	1,206	375,414	376,621
Shaft at Point G	33,086		430'631	504,301
Construction Tunnel at Point H	0	244,081	750,620	994,701
Shaft at Point H	0	7,329	421,401	428,730
Shaft at Point I	6,528	0	796,634	803,161
Shaft at Point J	6,528	0	805,629	812,157
Shaft at Point K	13,381	0	610,972	624,353
Shafts at Point L	29,990	0	631'117	701,690
<b>Total Spoil Volume</b>	<b>366,500</b>	<b>261,422</b>	<b>8'370'487</b>	<b>8'998'409</b>

PhD student (M. Haas) working on spoil re-use

# Future Studies

- Refine design for underground structures and confirm surface structures requirements
- A cost analysis to verify if it is feasible having a bigger diameter tunnel instead of two parallel eh main tunnel and the RF tunnel, separated by a concrete shield wall
- Preparing the site investigations campaign
- Footprint optimization of FCC, including surface sites
- Currently looking to improve the alignment optimisation tools – Tunneling Workshop 24-25 October

<https://indico.cern.ch/event/823271/>

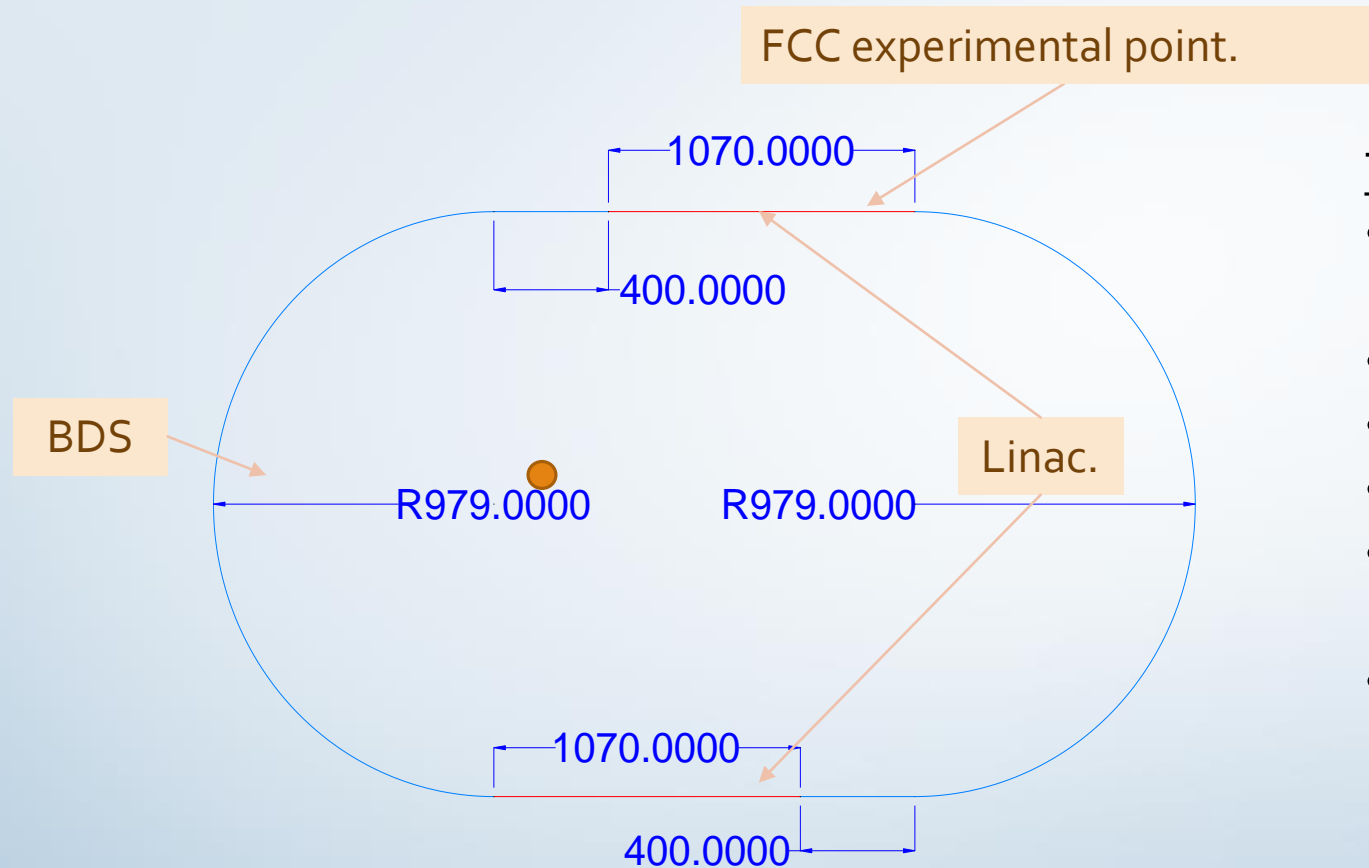
Thank you for your  
attention!

The image features a light blue background with a white-to-light-blue gradient. In the bottom-left corner, there are three diagonal stripes: a dark grey stripe, a thin white stripe, and a wider orange stripe.



Back up slides

# FCC-eh layout configuration



## Tunnel Dimensions:

- 400m Beam Delivery System (BDS)
- 1070m Linac
- 979m radius arcs (x2)
- 400m drift section.
- **Total Length of main tunnel = 9091m.**
- **Total Length of RF Tunnel = 2140m**

# Tunnel Optimisation Tool

**Alignment**   **Shafts**   **Query**

Choose alignment option

Tunnel elevation at centre: 322mASL

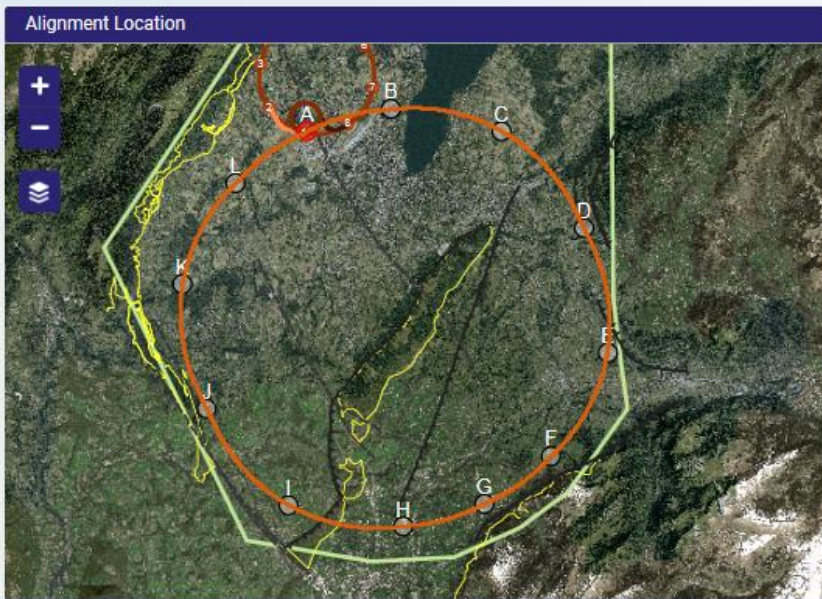
Grad. Params

Azimuth (\*): -75.5  
 Slope Angle x-x(%): 0.3  
 Slope Angle y-y(%): 0.08

**LOAD**   **CREATE**   **UPDATE**   **CALCULATE**

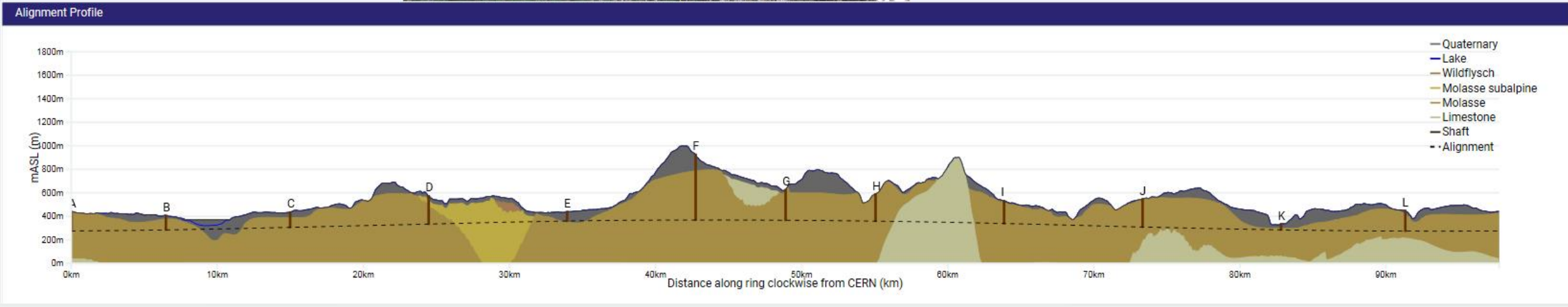
Alignment centre  
 X: 2499941   Y: 1107760

	CP 1		CP 2	
	Angle	Depth	Angle	Depth
LHC	38°	48m	-41°	88m
SPS		121m		127m
T12		121m		127m
T18		51m		119m



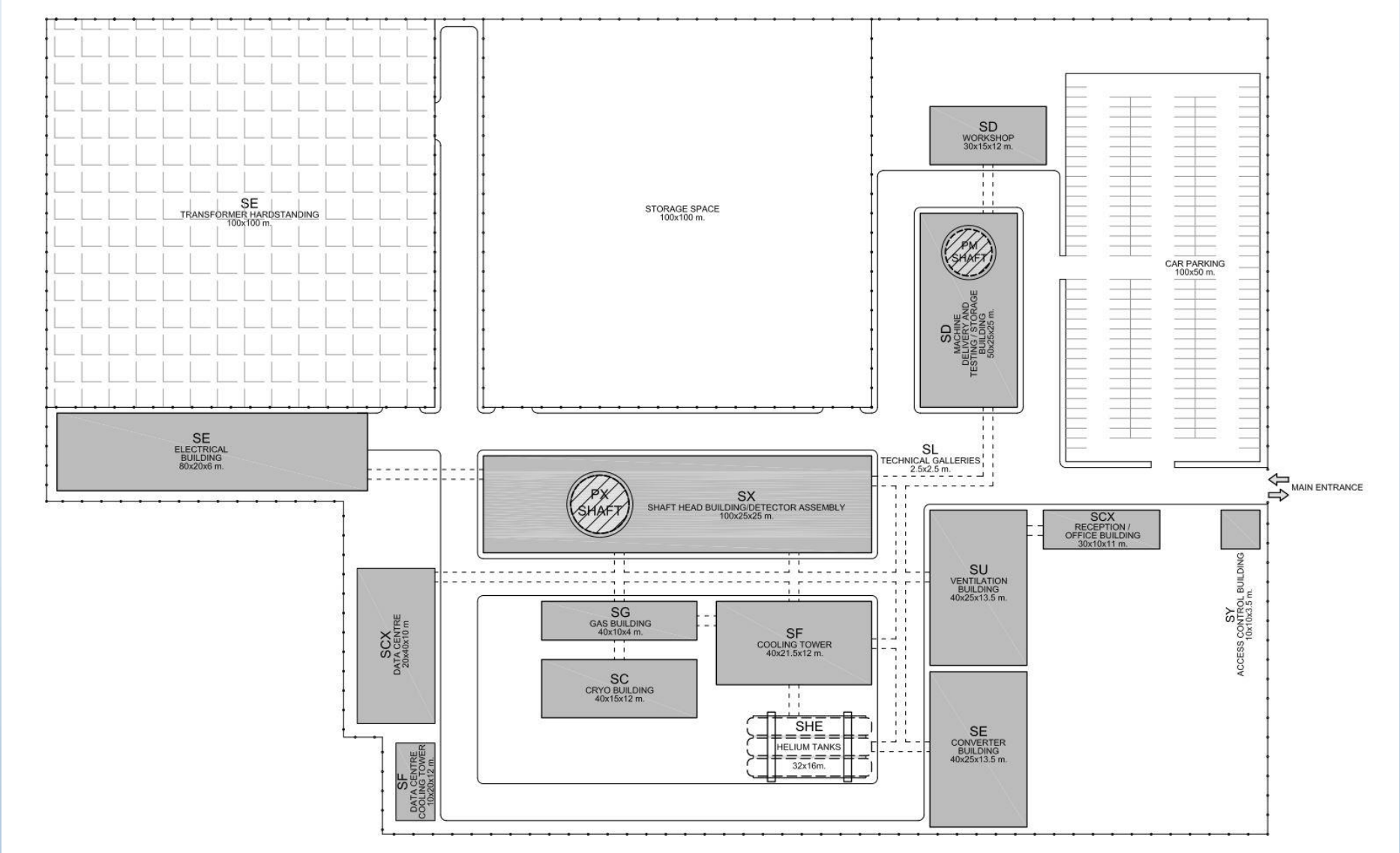
**Geology Intersected by Shafts**   **Shaft Depths**

Point	Actual	Shaft Depth (m)				Geology (m)	
		Molasse SA	Wildflysch	Quaternary	Molasse	Urgonian	Limestone
A	166	0	0	13	153	0	0
B	123	0	0	29	94	0	0
C	130	0	0	47	83	0	0
D	240	45	0	40	155	0	0
E	79	0	0	79	0	0	0
F	558	0	0	139	419	0	0
G	259	0	0	13	246	0	0
H	230	0	0	0	230	0	0
I	193	0	0	13	181	0	0
J	237	0	0	6	231	0	0
K	51	0	0	36	15	0	0
L	175	0	0	24	151	0	0
<b>Total</b>	<b>2442</b>	<b>45</b>	<b>0</b>	<b>439</b>	<b>1958</b>	<b>0</b>	<b>0</b>

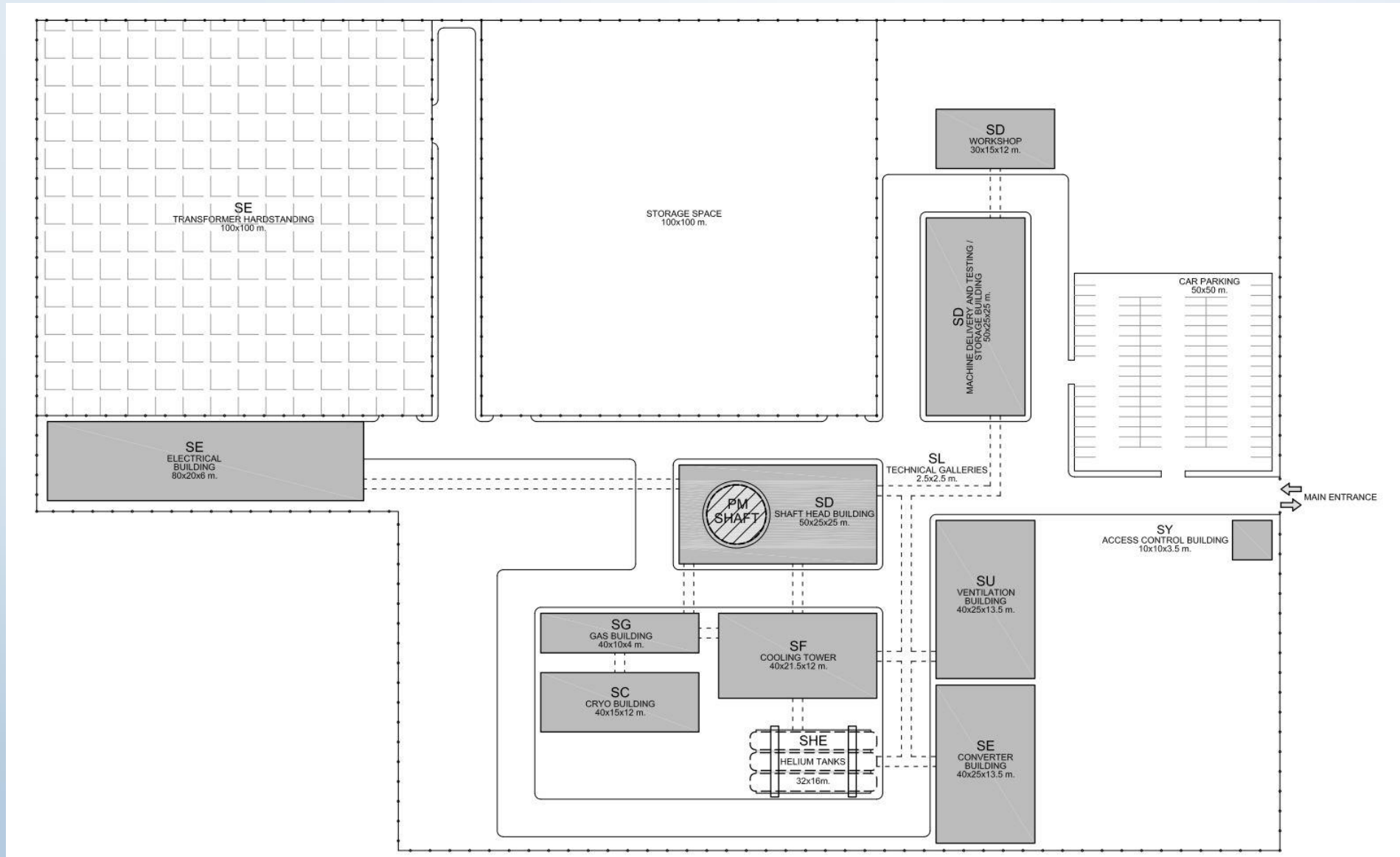


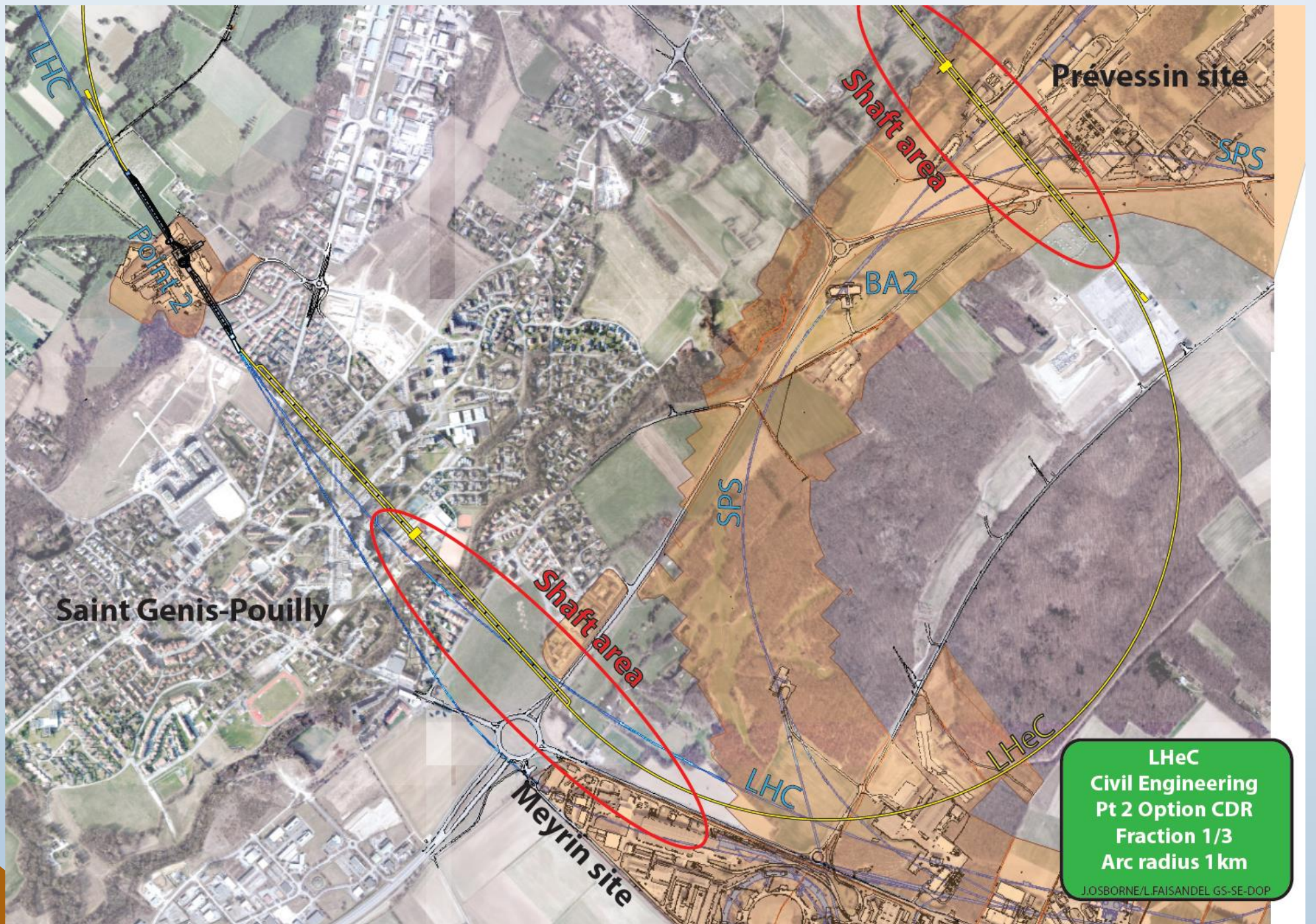


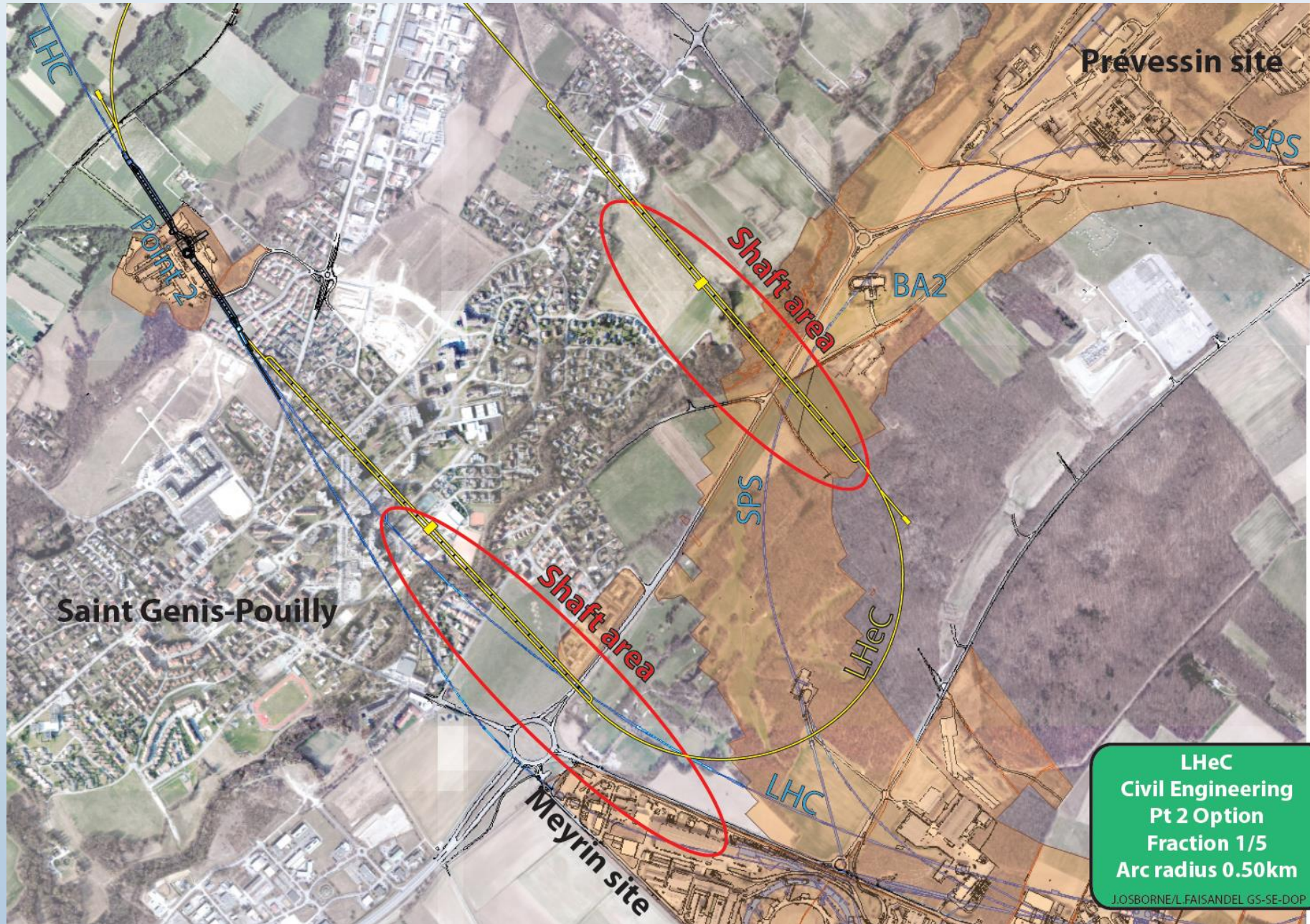
# General arrangement of FCC experimental site



# FCC access site - general arrangement







Préveessin site

SPS

Point 2

BA2

Shaft area

Shaft area

Saint Genis-Pouilly

LHC

Meyrin site

LHeC  
Civil Engineering  
Pt 2 Option  
Fraction 1/5  
Arc radius 0.50km

J.OSBORNE/L.FAISANDEL GS-SE-DOP