Civil Engineering for FCC-eh and LHeC

Matthew Stuart , John Osborne & Jo Stanyard (SMB - Site Engineering - FAS Section)

Acknowledgements to Max Klein, Oliver Bruning, Alex Bogacz & Frank Gerigk.

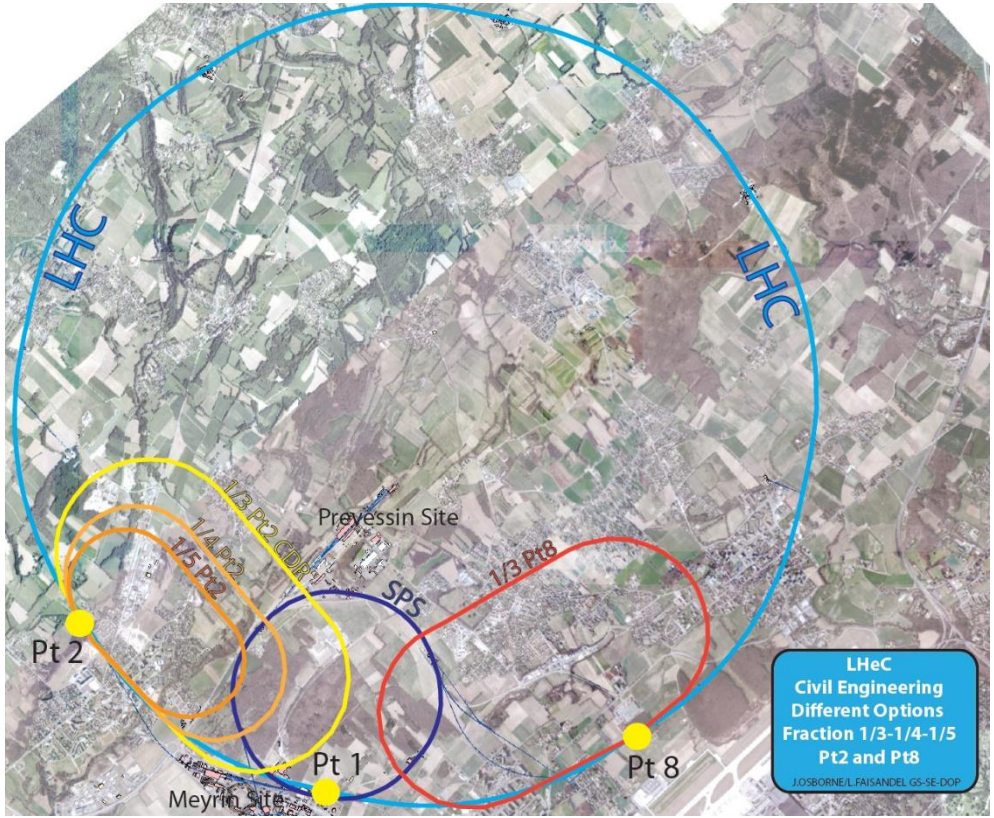
Introduction

- Scope of LHeC & FCC-eh Civil Engineering
- A recap of the LHeC proposal and the options presented at previous FCC weeks.
- Changes to the FCC layout and the impact on FCC-eh position
- Preferred FCC-eh position
- LHeC and FCC-eh Cross-sections
- Future Challenges

Scope of LHeC Civil Engineering

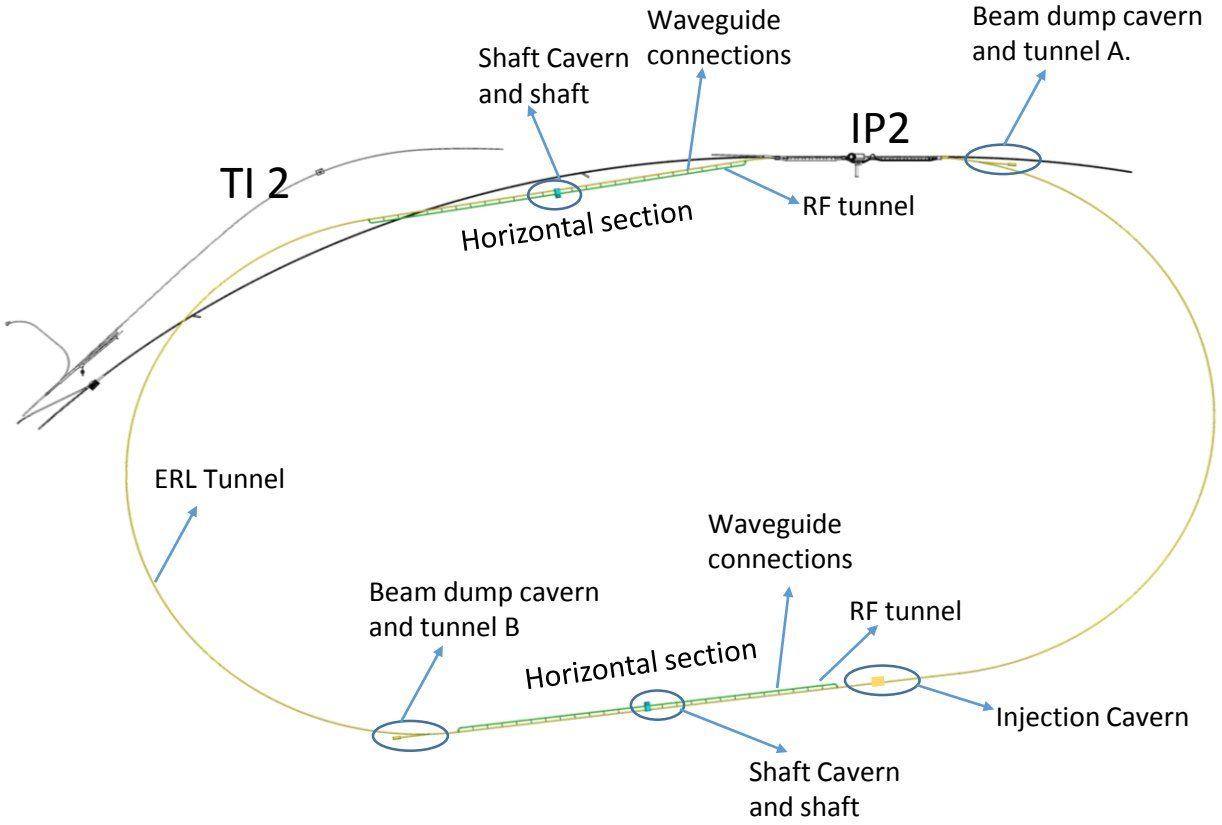
FCC-eh – Alternative Dimensions:

- It was proposed that the LHeC machine could be scaled down to:
  - 1/5
  - 1/4
  - 1/3
- Allows reduced cost of tunnelling.
- Other structures would remain the same.
- Point 2 preferred as it allows infrastructure to be located on CERN land.



Scope of LHeC Civil Engineering

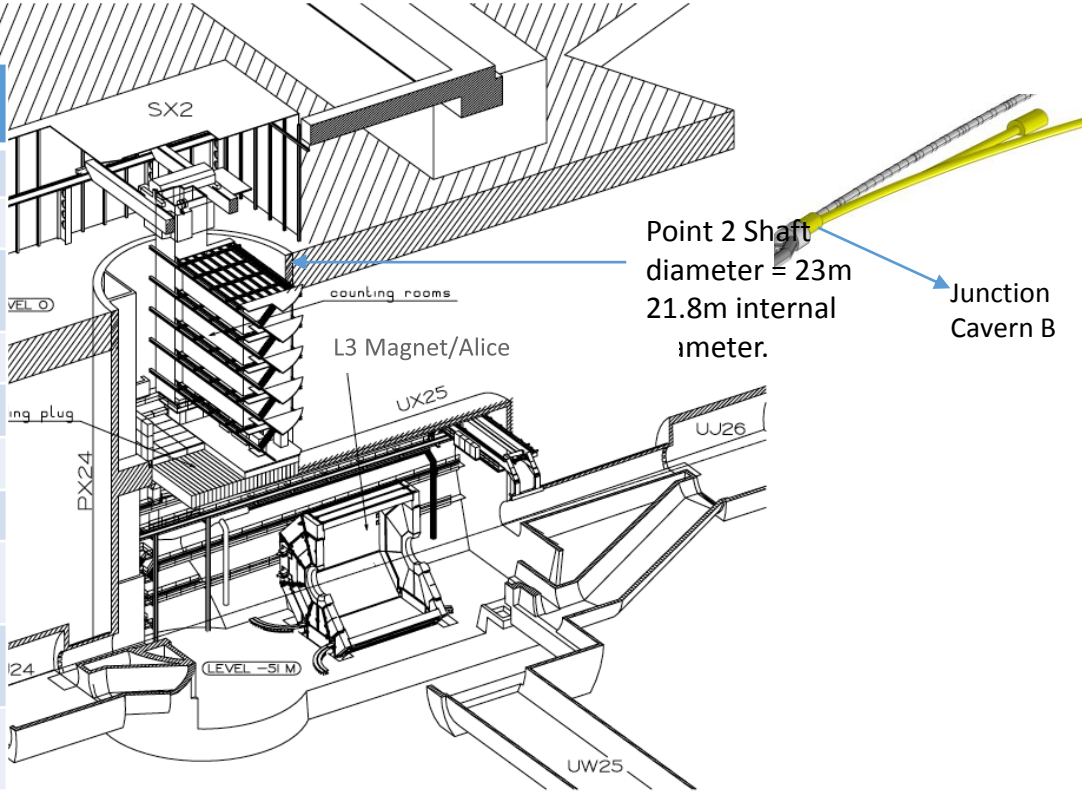
Type	No.	Dia. (m)	Length (m)	Total Length (m)
Shaft Cavern	2	20	30	60
Shaft	2	8	80	160
Injection Cavern	1	30	30	30
Dump Cavern	2	12	20	40
Dump tunnel	2	5	90	180
RF Tunnel	2	6	1070 x 2	2140
ERL Tunnel	1	5	9091	9091
Waveguide connections	50	1	10	500
Junction Cavern A	1	20	55	55
Junction Cavern B	1	20	55	55



John Osborne June 26th 2014

Scope of LHeC Civil Engineering

Type	No.	Dia. (m)	Length (m)	Total Length (m)
Shaft Cavern	2	20	30	60
Shaft	2	8	80	160
Injection Cavern	1	30	30	30
Dump Cavern	2	12	20	40
Dump tunnel	2	5	90	180
RF Tunnel	2	6	1070 x 2	2140
ERL Tunnel	1	5	9091	9091
Waveguide connections	50	1	10	500
Junction Cavern A	1	20	55	55
Junction Cavern B	1	20	55	55



John Osborne June 26th 2014

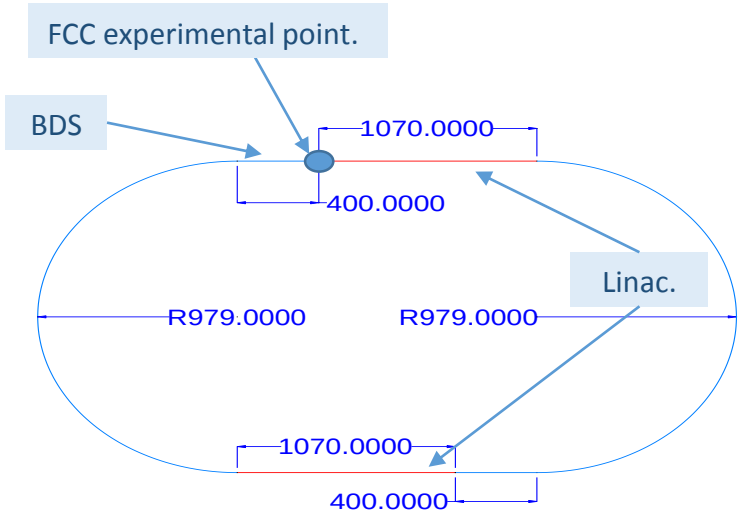
Scope of FCC-eh Civil Engineering

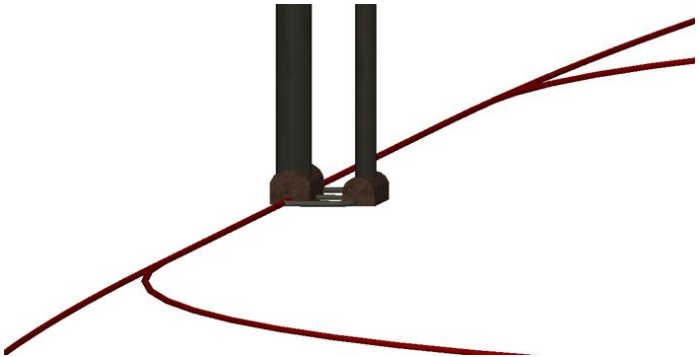
Tunnel Dimensions:

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

Cavern and shaft requirements:

- Experimental shaft and cavern
  - 15m dia. 175m depth Shaft proposed for Point L
- Access shaft and cavern



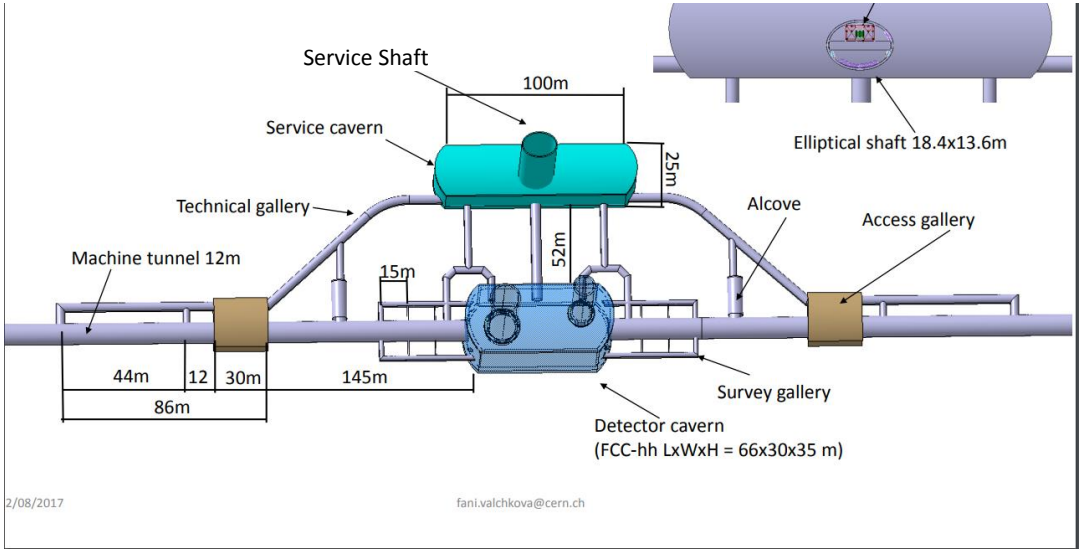


Tunnel Dimensions:

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

Cavern and shaft requirements:

- Experimental shaft and cavern
  - 15m dia. 175m depth Shaft proposed for Point L
- Access shaft and cavern



Point L

- Geological risk – Karstic Limestone.
- Further probing to check geology required.

Point B

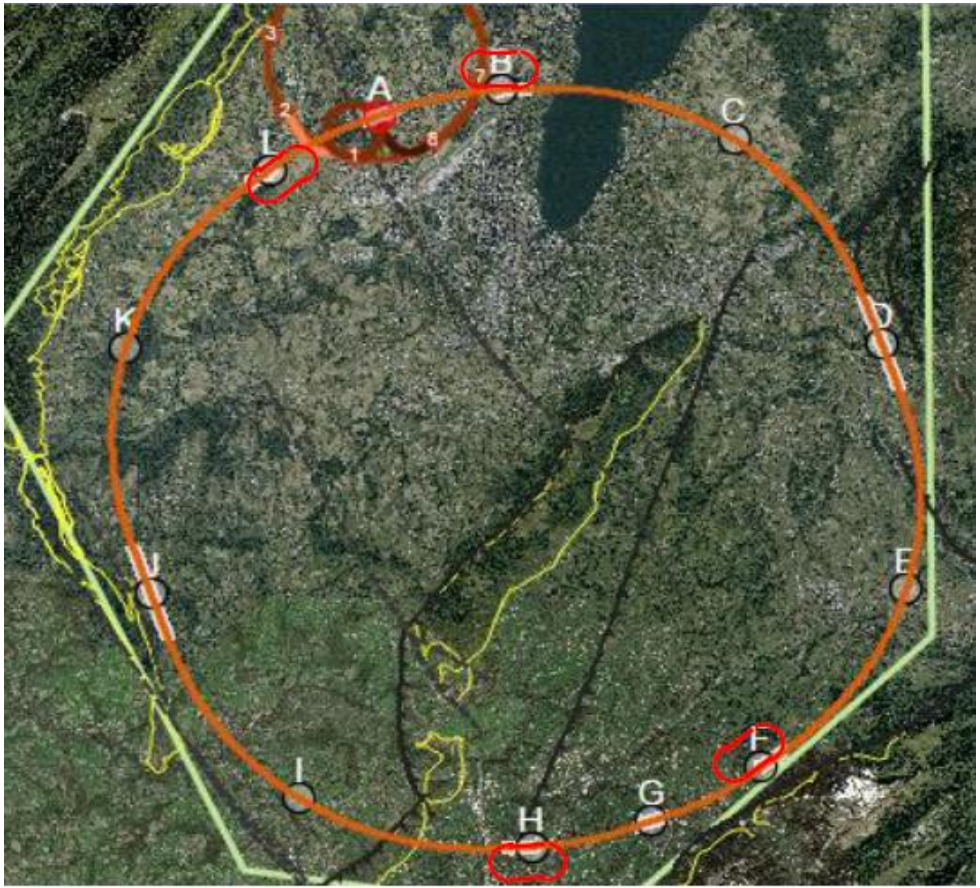
- Low geological risk (molasse) anticipated but could encounter Jura limestone.

Point F

- High geological uncertainty in this region
- Very far from existing CERN sites.

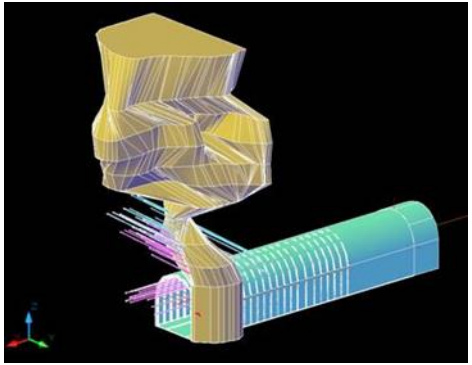
Point H

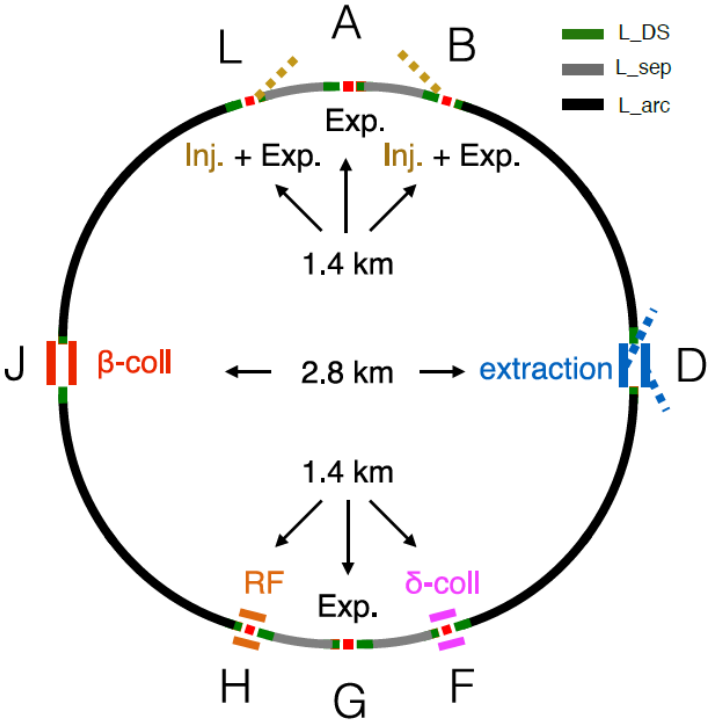
- Very far from existing CERN sites
- Low geological risk (molasse).

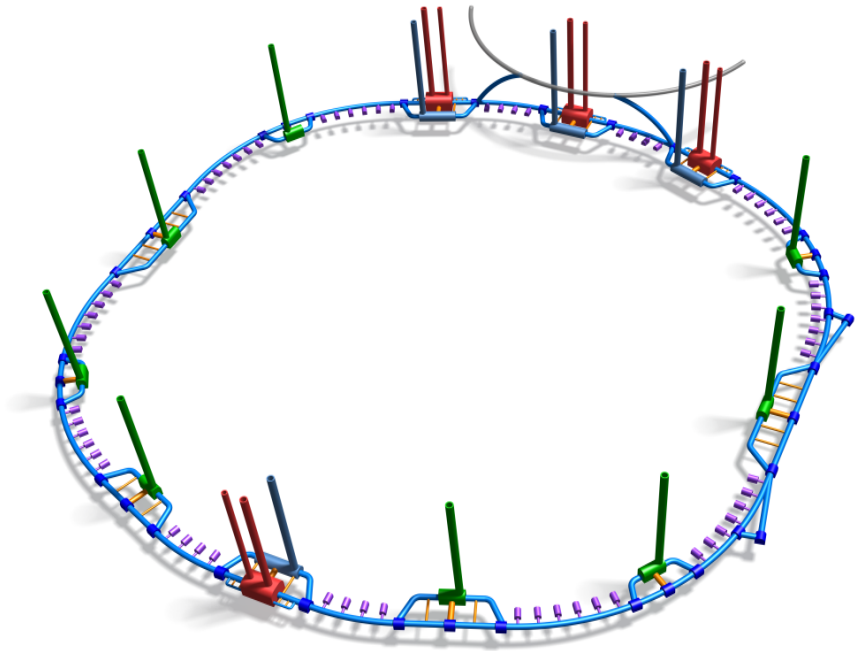


Limestone Properties:

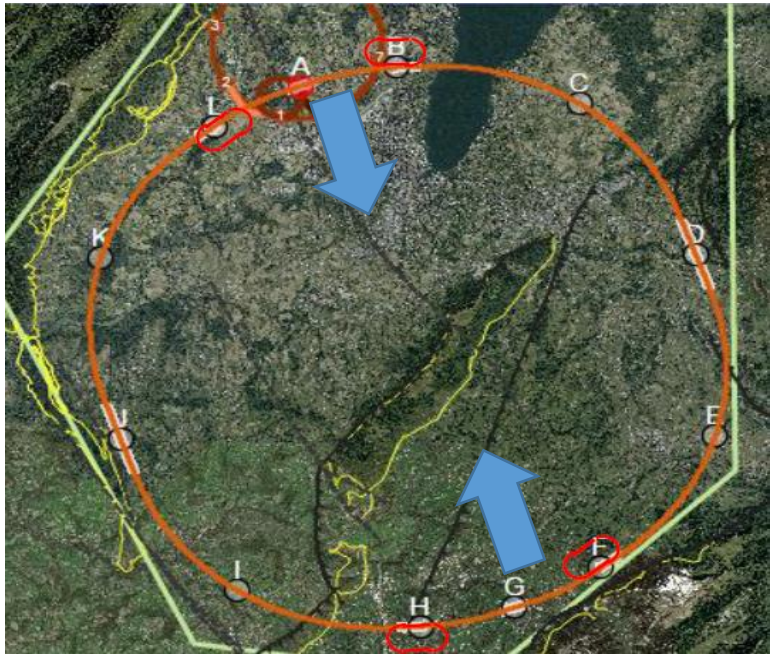
- Hard rock
- Normally considered as sound tunneling rock
- In this region fractures and karsts encountered
  - Risk of tunnel collapse
  - High inflow rates measured during LEP construction (600L/sec)
  - Clay-silt sediments in water
  - Rockmass instabilities




A
L
B
L_DS
L_sep
L_arc
Exp.
Inj. + Exp.
Inj. + Exp.
1.4 km
J
β-coll
2.8 km
extraction
D
1.4 km
RF
Exp.
δ-coll
H
G
F



Rome 2016 Layout



Updates since FCC Week 2016 layout:

- Reduced depth below surface level.
- Reduced length of straight sections at J and D.
- Increased tunnel length from A-L, A-B and G-F, G-H.
- Avoids Jura Limestone and Pre-Alps region.
- Reduced Total Tunnel Length.

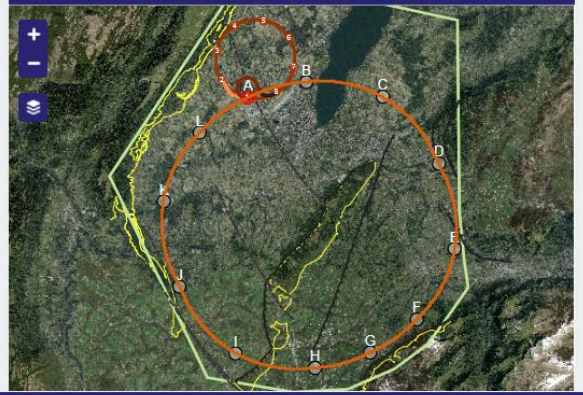
FCC Layout Updates 2017

Alignment | Shafts | Query

Highlights:

- Avoids Jura and Pre-Alps Limestone.
- Only one sector containing Limestone.
- Significantly reduced total shaft length.
- Experimental Site at Point A on existing CERN land.
- Avoids extremely large overburden (with the exception of point F – alternative access options being considered).

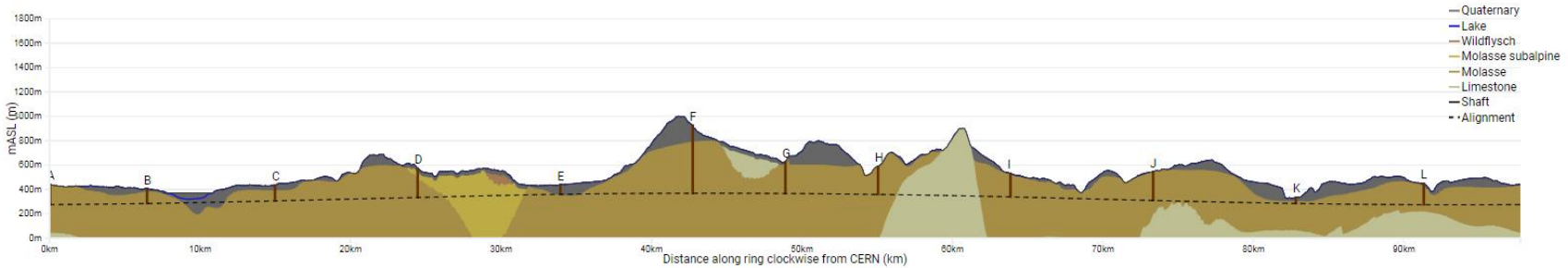
Alignment Location



Geology Intersected by Shafts | Shaft Depths

Point	Actual	Shaft Depth (m) Molasse SA	Wildflysch	Quaternary	Geology (m) 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
Total	2442	45	0	439	1958	0	0

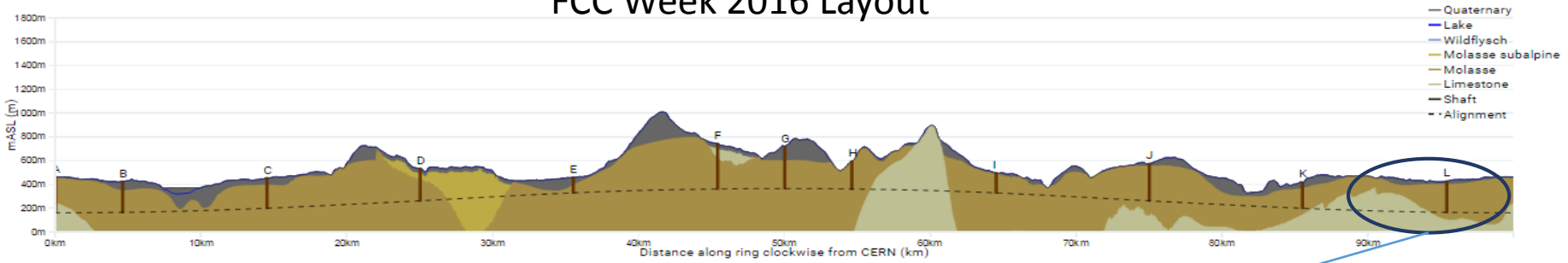
Alignment Profile



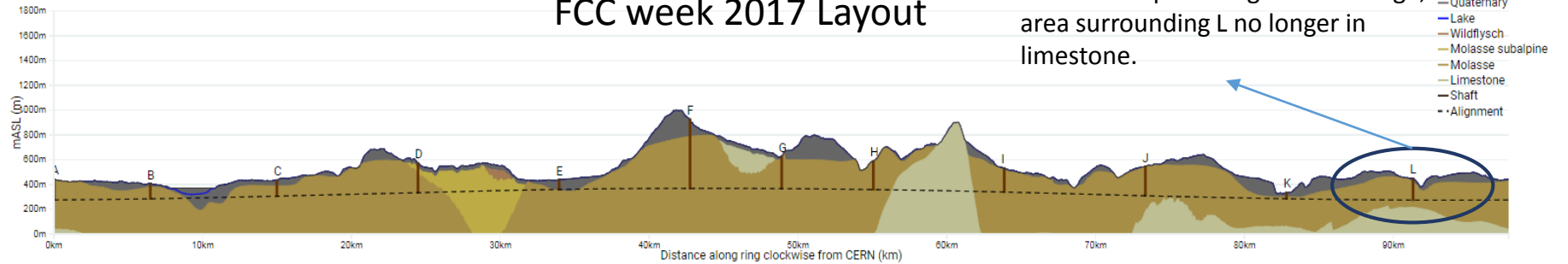
Geology Intersected by Tunnel | Geology Intersected by Section

FCC Layout Update (profile)

FCC Week 2016 Layout



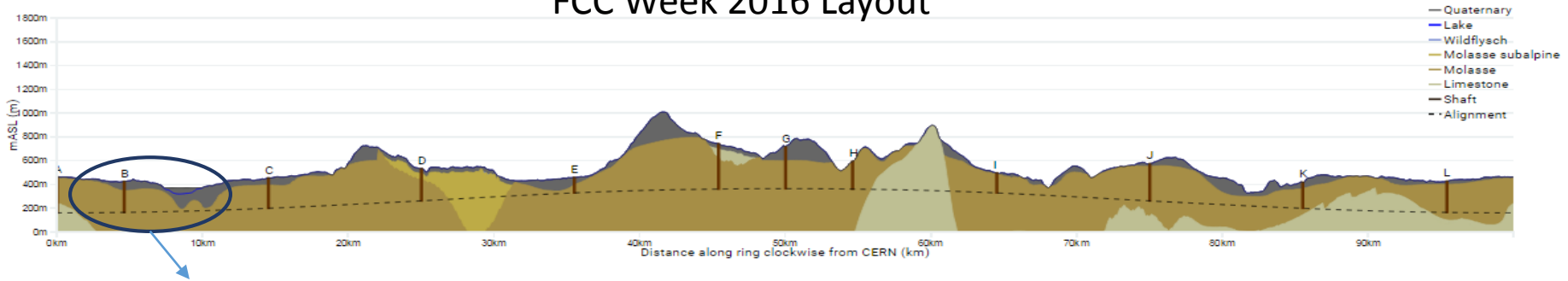
FCC week 2017 Layout



Reduced Depth & alignment change; area surrounding L no longer in limestone.

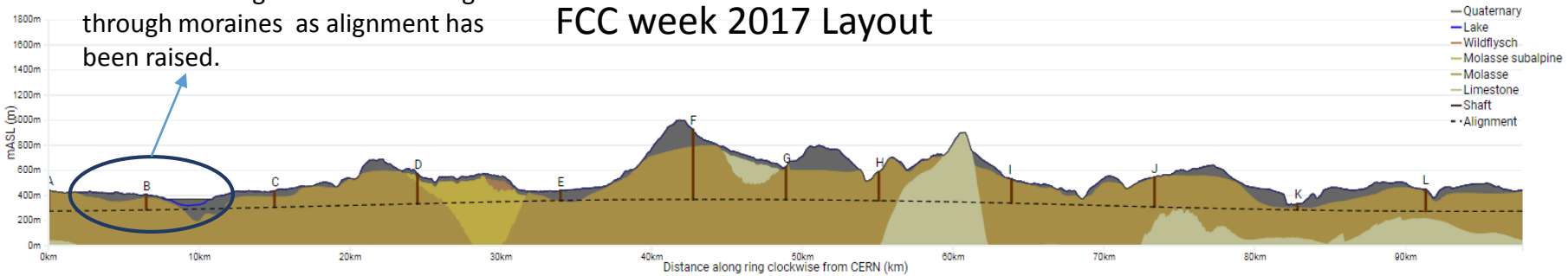
FCC Layout Update (profile)

FCC Week 2016 Layout



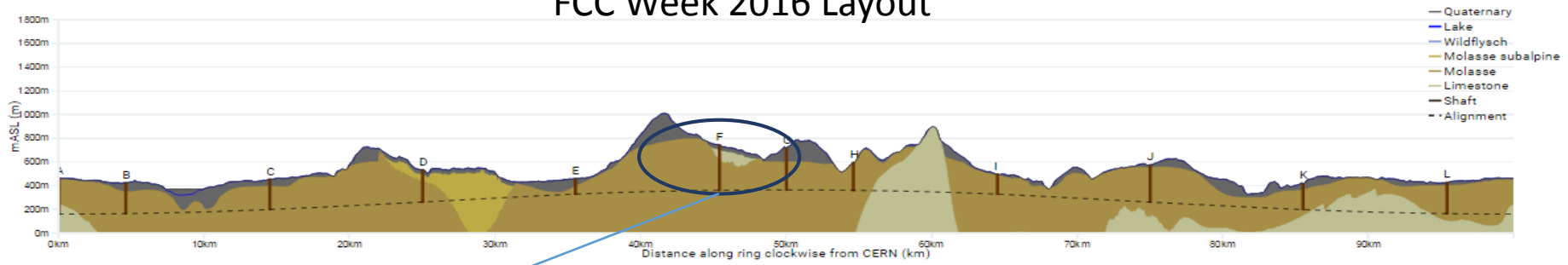
Introduced a high risk of tunnelling through moraines as alignment has been raised.

FCC week 2017 Layout



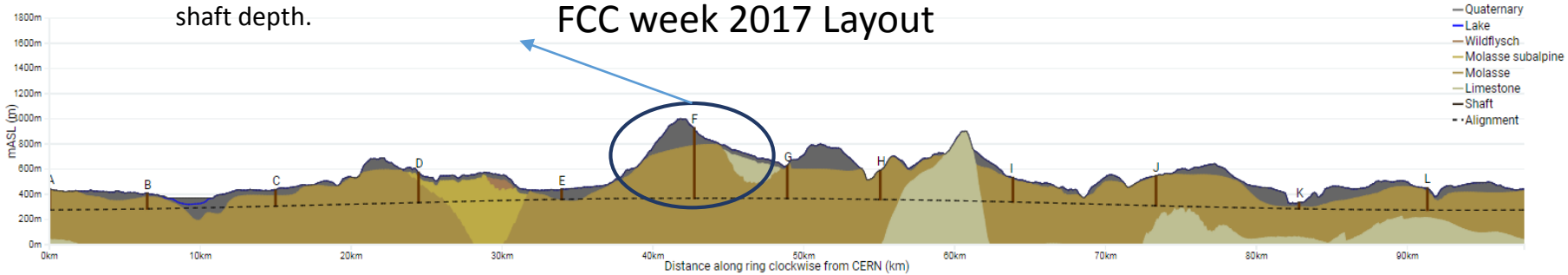
FCC Layout Update (profile)

FCC Week 2016 Layout



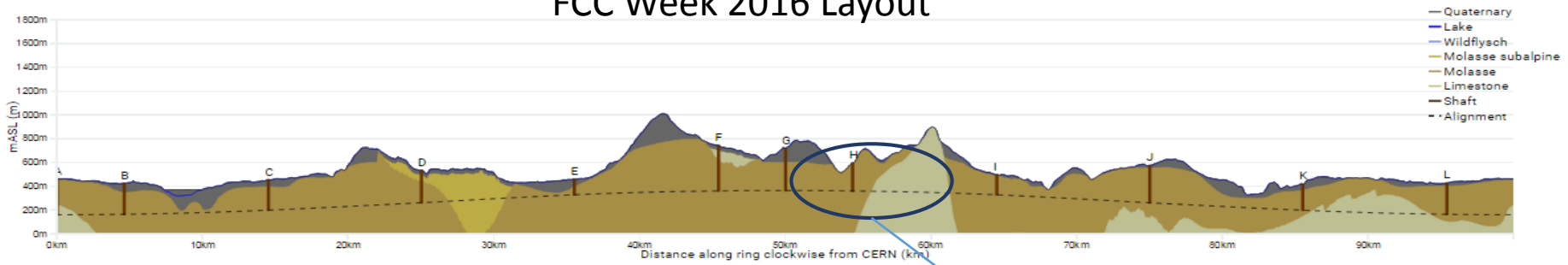
Access more difficult and increased shaft depth.

FCC week 2017 Layout

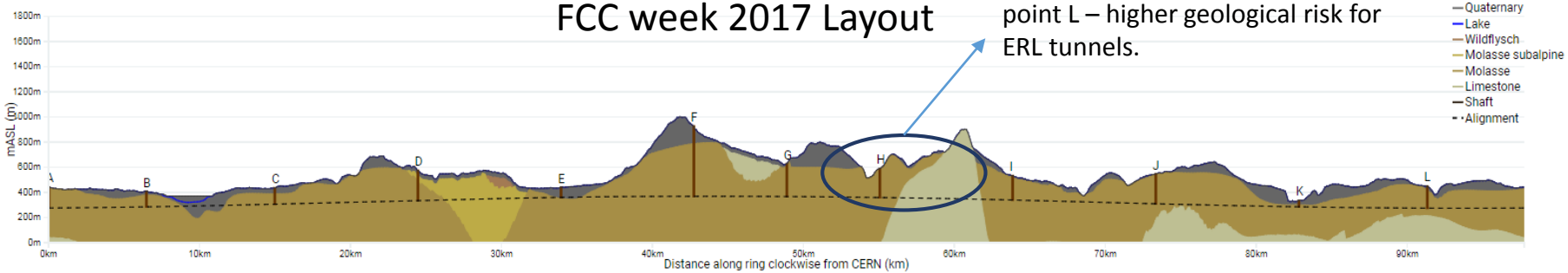


FCC Layout Update (profile)

FCC Week 2016 Layout



FCC week 2017 Layout



Closer proximity to limestone than point L – higher geological risk for ERL tunnels.

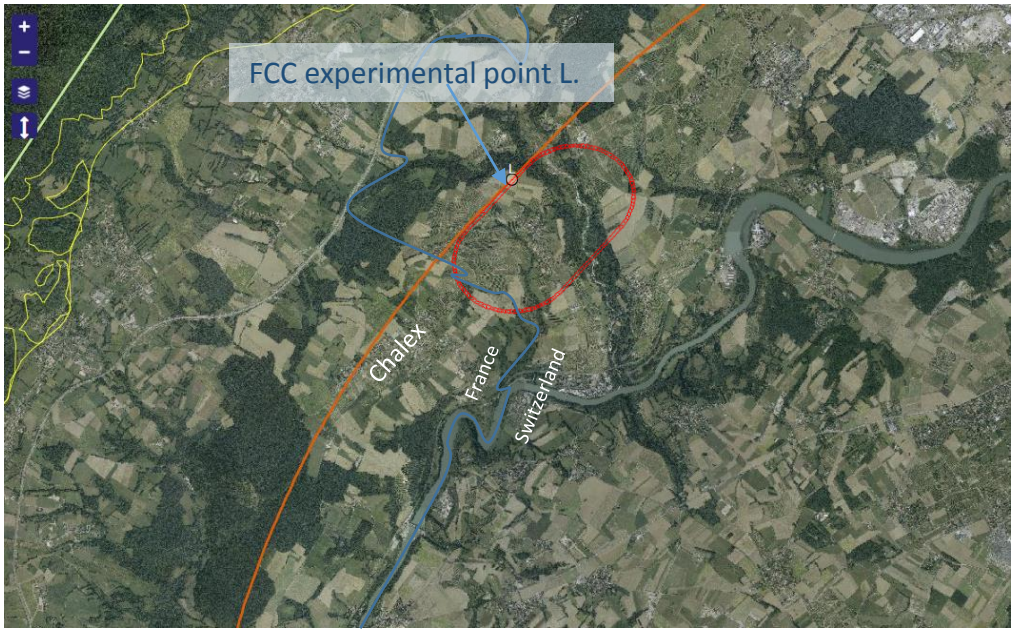
Why is experimental point L preferred?

Positives:

- 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 problems:

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

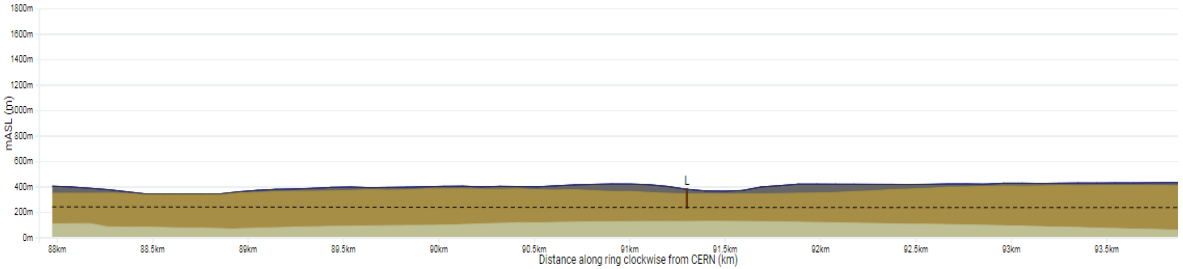


FCC-eh Geology

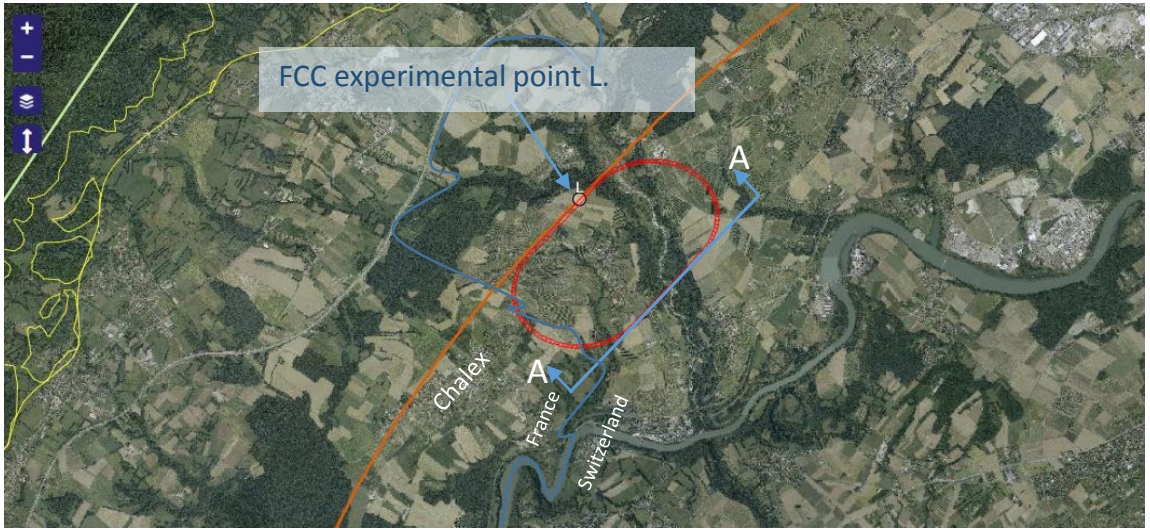
Geology:

Manipulated FCC TOT to show a cross section of geology through the location of the FCC-eh tunnels:

- FCC eh tunnels should aim to be located in 100% Molasse.
- Approximately 180m – 215m deep shafts located mainly in molasse with the exception of the moraines at the surface.
- Shafts avoid Nature Reserves and watercourses. (However, both shafts are located in Switzerland)



Cross Section of Geology at A-A



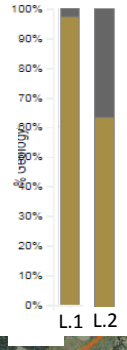
Geology:

Manipulated FCC TOT to show a cross section of geology through the location of the FCC-eh tunnels:

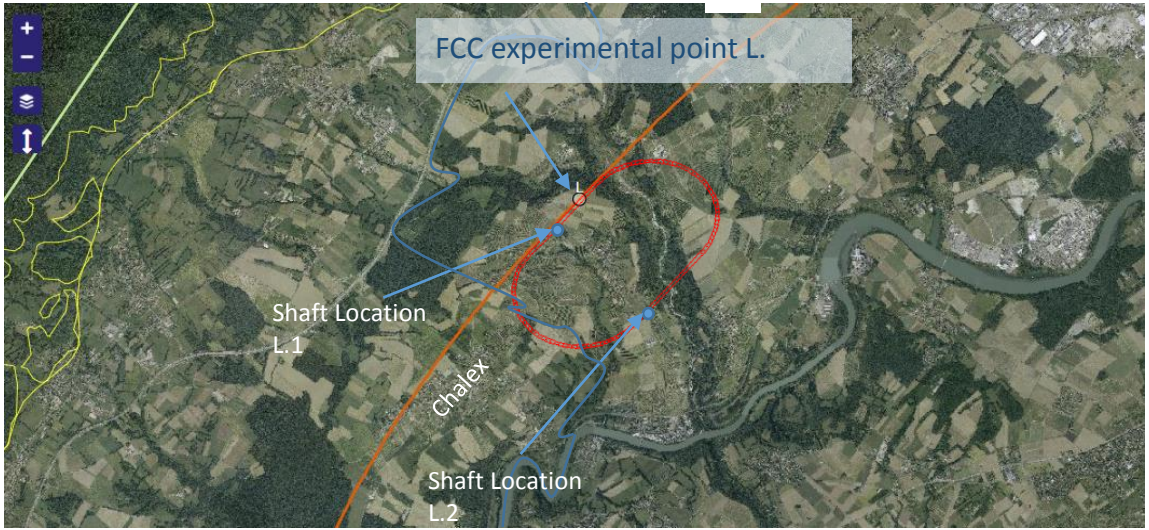
- FCC eh tunnels should aim to be located in 100% Molasse.
- Approximately 180m – 215m deep shafts located mainly in molasse with the exception of the moraines at the surface.
- Shafts avoid Nature Reserves and watercourses. (However, both shafts are located in Switzerland)

	Shaft Depth (m)			Geology (m)			
Point	Actual	Molasse SA	Wildflysch	Quaternary	Molasse	Urgonian	Limestone
L.1	215	0	0	6	208	0	0
L.2	185	0	0	67	118	0	0

Small variation in shaft location will change the geology.



L.2:
Shaft depth: 179 m
Molasse: 97%
Moraines: 3%



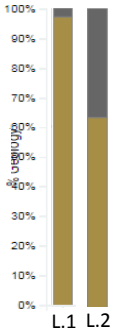
Geology:

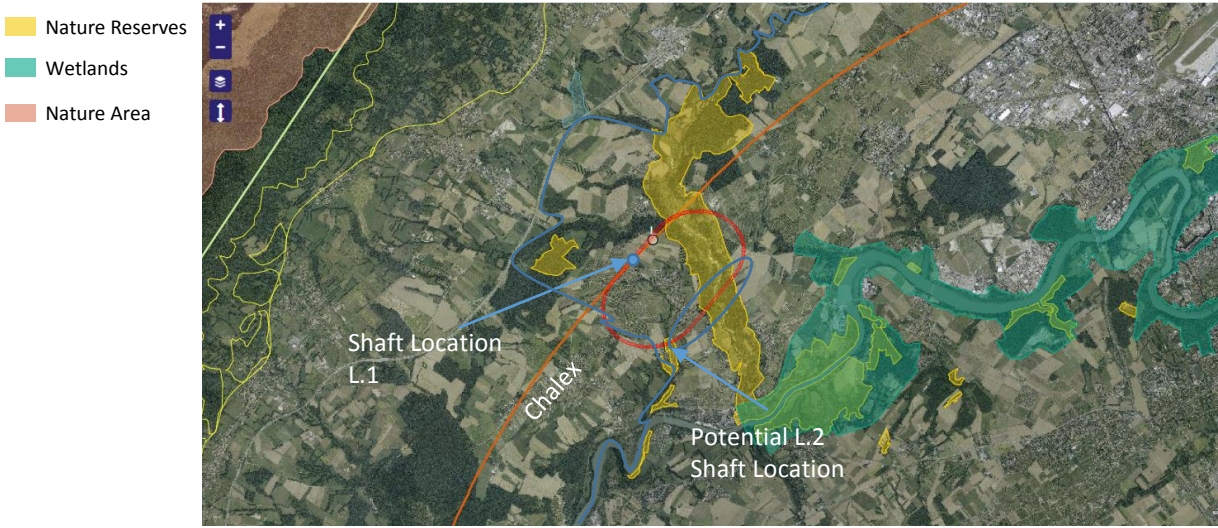
Manipulated FCC TOT to show a cross section of geology through the location of the FCC-eh tunnels:

- FCC eh tunnels should aim to be located in 100% Molasse.
- Approximately 180m – 215m deep shafts located mainly in molasse with the exception of the moraines at the surface.
- Shafts avoid Nature Reserves and watercourses. (However, both shafts are located in Switzerland)

	Shaft Depth (m)			Geology (m)			
Point	Actual	Molasse SA	Wildflysch	Quaternary	Molasse	Urgonian	Limestone
L.1	215	0	0	6	208	0	0
L.2	185	0	0	67	118	0	0

Small variation in shaft location will change the geology.



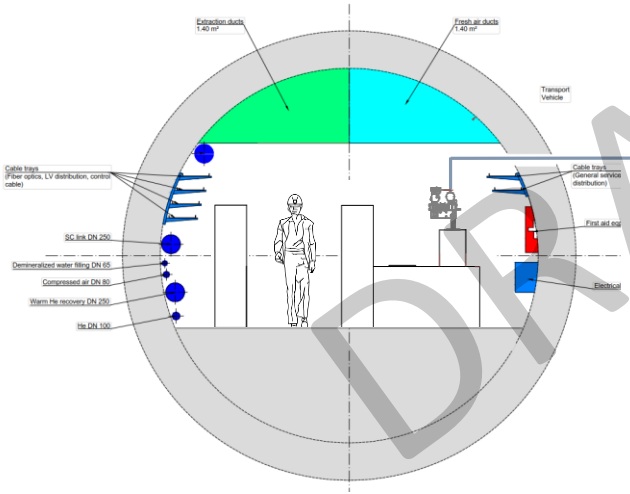


ERL Tunnel – LHeC & FCC-eh Straight Section

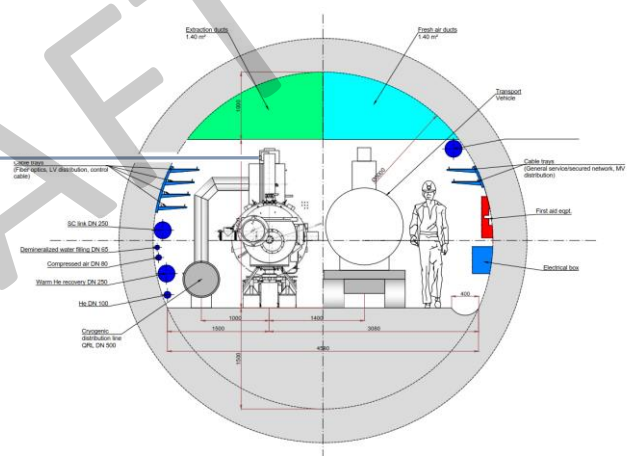
Please note this is a draft cross-section used to identify an adequate diameter for the ERL Tunnel.

- 5m appears to be a reasonable diameter at this stage (compared to 6m for FCC).
- This corresponds to the 5.2m used by the European XFEL.
- The arcs could potentially be smaller (this would depend on the requirements for Cooling and Ventilation).
- Services are assumptions to allow an estimate of the tunnel diameter to be produced.
- A full integration study will be required to achieve a complete tunnel cross-section.

RF Tunnel



Machine Tunnel



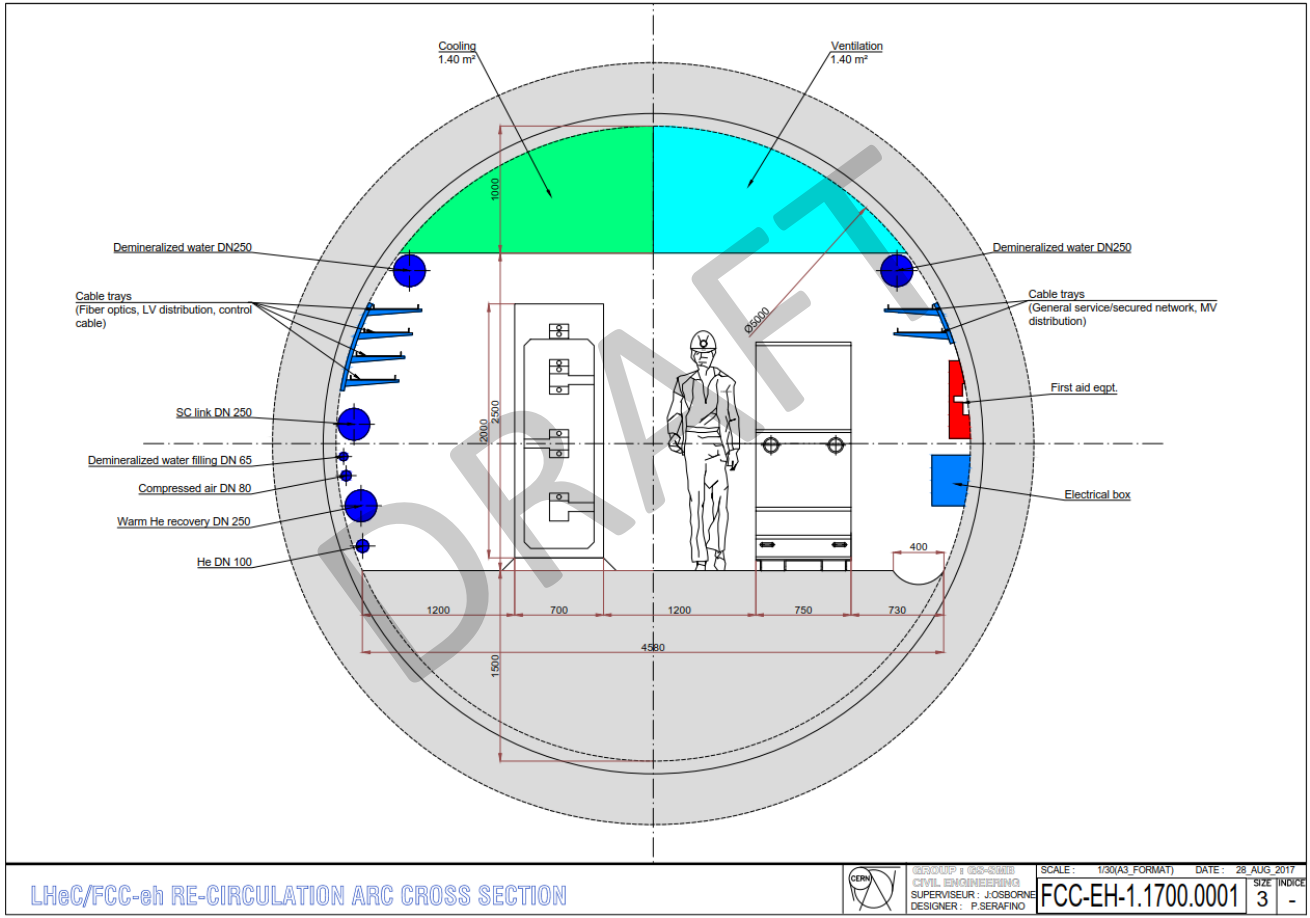
- Similar to High Powered SPL
- RF supply tunnel diameter 6m (2014 report)
  - Information on klystron and modulator dimensions required as well as the required services.
- Removes requirement for multiple shafts to supply power from the surface.

Thanks to A.Bogacz & F.Gerigk

ERL Tunnel – LHeC & FCC-eh Arcs

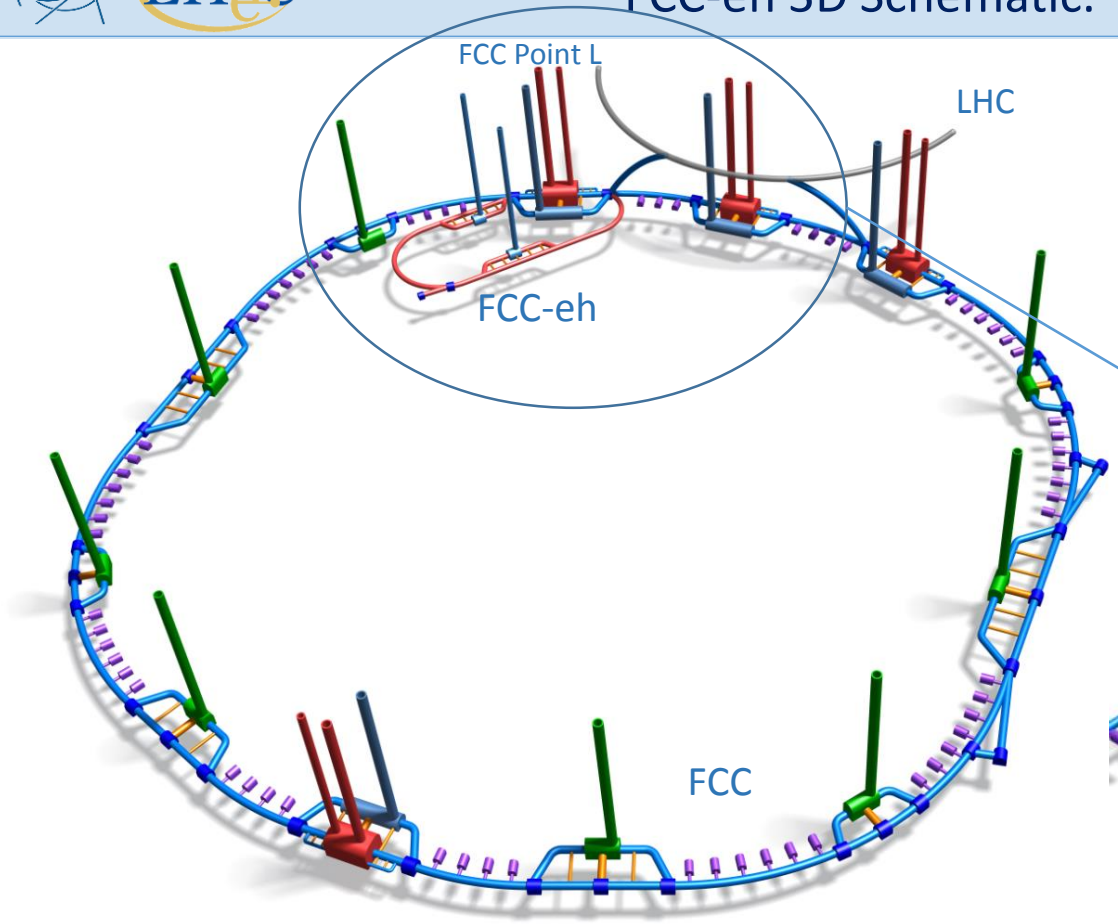
Please note this is a draft cross-section used to identify an adequate diameter for the ERL Tunnel.

- 5m appears to be a reasonable diameter at this stage (compared to 6m for FCC).
- This corresponds to the 5.2m used by the European XFEL.
- The arcs could potentially be smaller (this would depend on the requirements for Cooling and Ventilation).
- Services are assumptions to allow an estimate of the tunnel diameter to be produced.
- A full integration study will be required to achieve a complete tunnel cross-section.

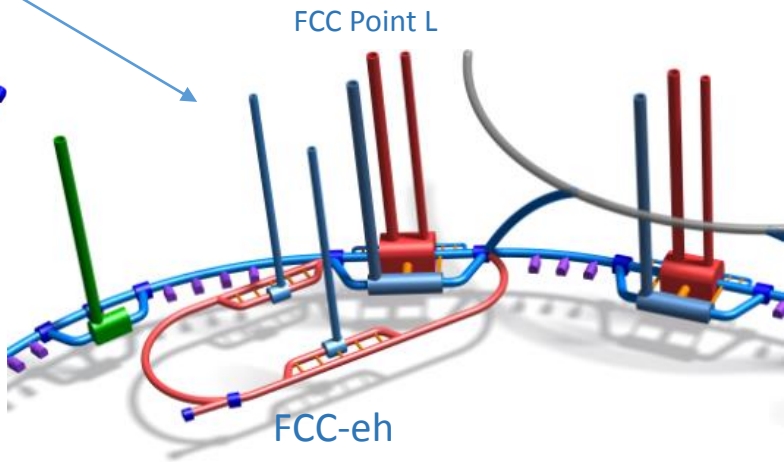


Thanks to A.Bogacz & F.Gerigk

FCC-eh 3D Schematic.

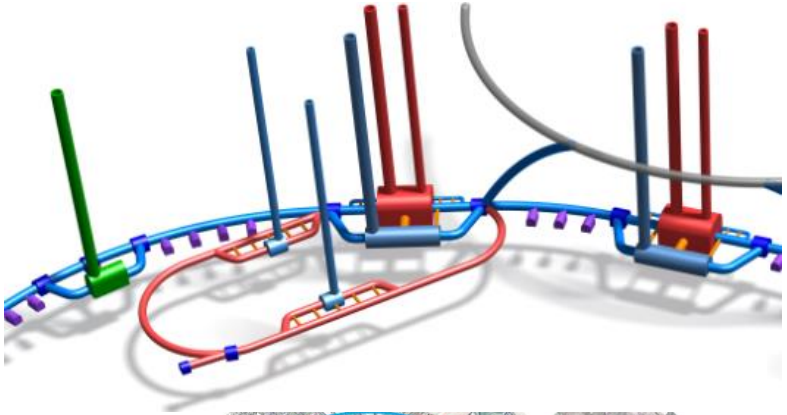


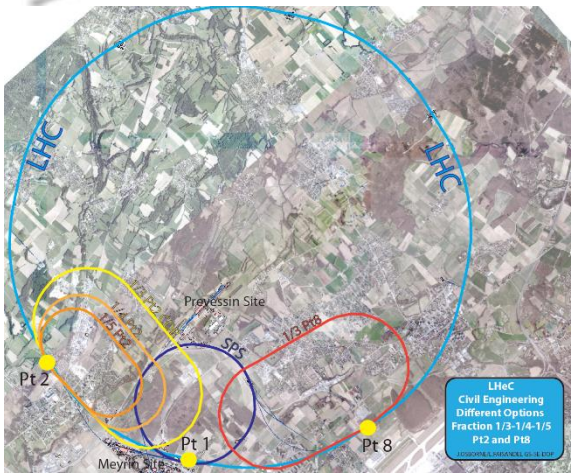
- The beam dump locations still need to be decided.
- Avoid clashes with alcoves
- Shaft locations can be changed.



Conclusions:

- Due to the new layout of FCC position L is the preferred location:
  - Good geological data and suitable geology.
  - Close to CERN but not interfering with current infrastructure.
- Still compatibility challenges to overcome:
  - Connection to FCC tunnel.
  - Layout to avoid other FCC structures.
- Other lengths are possible, this is a modular approach and can be attached to other projects.
- Infrastructure for FCC-eh located in Switzerland, for LHeC located in France.
- Using point 2 - all surface infrastructure can be located in France for LHeC.



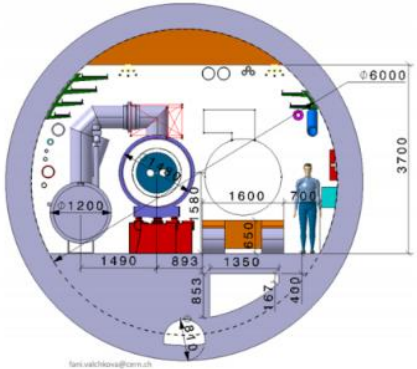


Summary – Future Steps

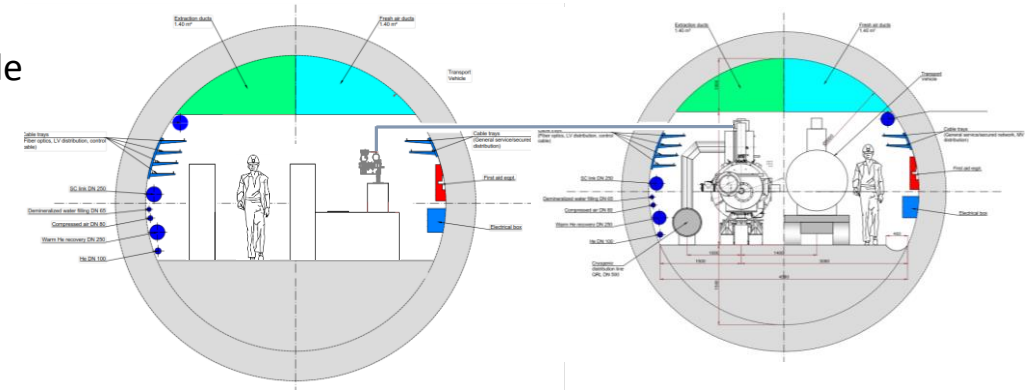
Future Steps:

- Continue the civil engineering feasibility study in more detail for location L:
  - Cost & schedule study
  - Integration study
- Continue to design a layout for the FCC-eh tunnels that is compatible with FCC infrastructure.
- Consultant to produce a cost and schedule study for FCC-eh.
- Possibility to study one machine for both LHC and FCC

FCC Tunnel



LHeC/FCC-eh Straight sections



www.cern.ch

FCC Dimensions

Point	Function	LSS length [km]	Depth [m]	Detector shaft Ø [m]	Access shaft Ø [m][1)]	Detector cavern LxWxH [m]	Service cavern[2)] LxWxH [m]	Technical galleries [km][3)]
A	Main experiment	1.4	152	15; 10	18	66x35x35	1XXx25x15	?
B	Side experiment; injection	1.4	121	15; 10	12	66x30x35	1XXx25x15	?
C	Mid-arc technical point	-	127	-	12	-	XXx25x15	-
D	Beam extraction	2.8	205	-	12	-	XXx25x15	± 1.4
E	Mid-arc technical point	-	89	-	12	-	XXx25x15	-
F	RF	1.4	476	-	12	-	XXx25x15	± 0.7
G	Main experiment	1.4	307	15; 10	18	66x35x35	1XXx25x15	?
H	Momentum collimation	1.4	266	-	12	-	XXx25x15	± 0.7
I	Mid-arc technical point	-	198	-	12	-	XXx25x15	-
J	Betatron collimation	2.8	248	-	12	-	XXx25x15	± 1.4
K	Mid-arc technical point	-	88	-	12	-	XXx25x15	-
L	Side experiment; injection	1.4	172	15; 10	12	66x30x35	1XXx25x15	?

1) Subject to outcome of transport and logistics study

2) Single combined service cavern (experiment/machine)
3) Waiting for replies from accelerator systems

FCC-eh – Alternative Dimensions

Different Options

- It was proposed that the LHeC machine could be scaled down to:
  - 1/5
  - 1/4
  - 1/3
- Allows reduced cost of tunnelling.
- When applied to FCC it allows different locations of tunnels and shafts to be studied.
  - More potential to avoid protected areas.
  - Can avoid clashes with FCC Alcoves.