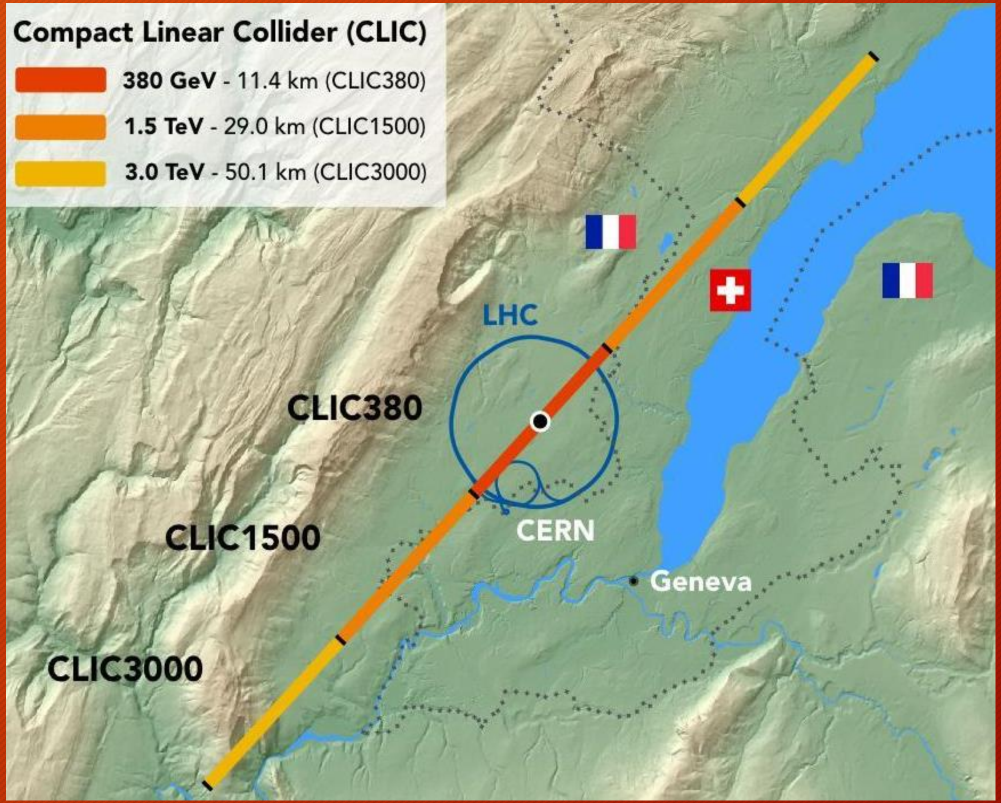
LCWS 2018, Texas, Arlington

CFS Overview for CLIC, FCC & Hi-Lumi

John Osborne – Matthew Stuart SMB-SE-FAS

Introduction

- 2018 CLIC status update
- CLIC Cost estimates for 380 GeV
- 2018 FCC status update
- Hi Lumi upgrade status



Representatives of the Civil Engineering, Infrastructure & Siting (CEIS) Working Group Disciplines:

Discipline	Representative
Chair & Civil Engineering	J.Osborne & Matthew Stuart
CLIC Link Persons	S.Stapnes/D.Schulte/C.Rossi/R.Corsini /W.Wuensch/A.Latina/D.Aguglia
Cooling and Ventilation (CV)	M.Nonis/P.Cabral
Electricity (EL)	Davide Bozzini
Survey (SU)	H.Mainaud Durand
Transport & Handling (HE)	I.Ruehl/Michal Czech
Interaction Region	K.Elsener
Logistics/Lab readiness	M.Tiirakari
CE Layouts & Cross-sections	SMB/CE Design Office
Health Safety & Environment (HSE)	S.Baird/S.Marsh
Schedule	K.Foraz/Marzia Bernardini
ILC Link Persons	J.Osborne/A.Yamamoto

General Objective: *Develop the existing layouts for the project from a civil engineering and technical infrastructure point of view, and work with the various actors towards a realistic design and project planning as needed for the 'CLIC Implementation Plan', due late 2018.*

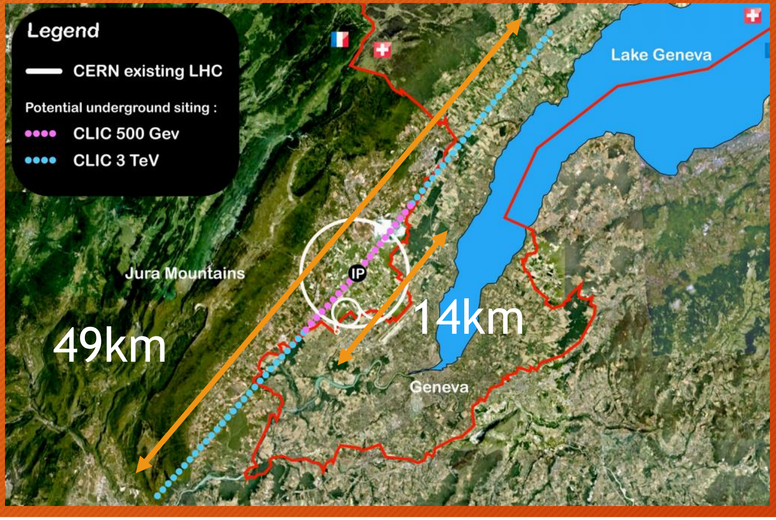
Meetings for the CEIS Working Group are taking place every 5 weeks to ensure full integration of the work done by each discipline.

Full Activity tracker updated at each meeting outlining the tasks for each discipline.

Status – CLIC CDR

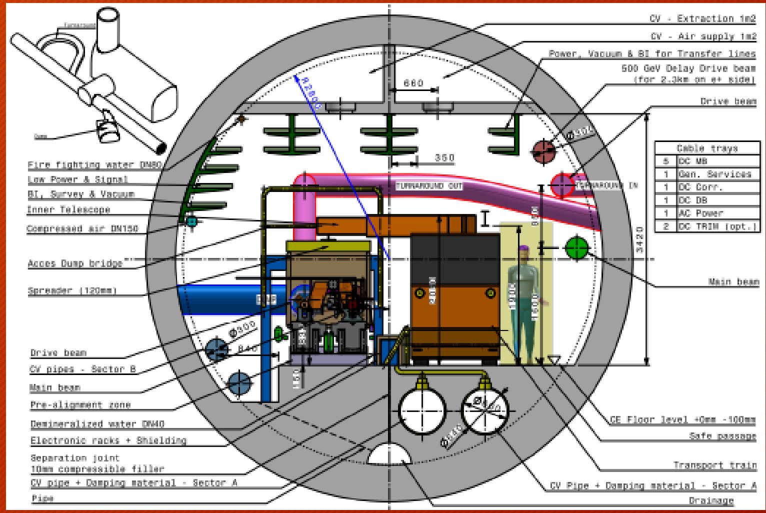
5.6m diameter 2 stage linear collider straddling the French & Swiss border:

- 500 GeV
- 3 TeV

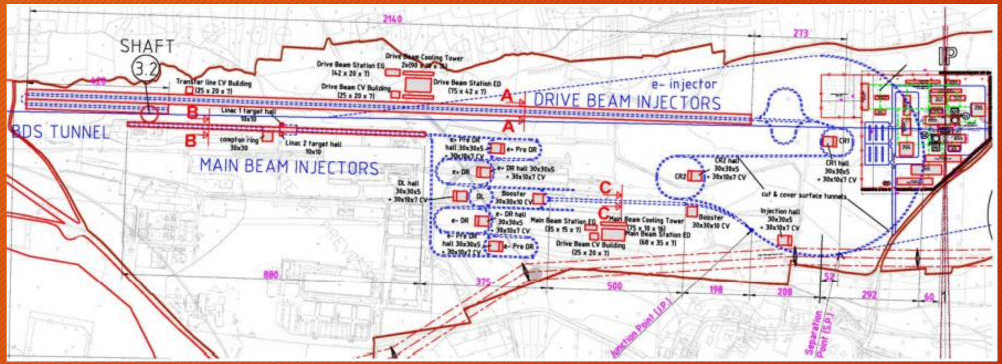


5.6m diameter main Linac to contain:

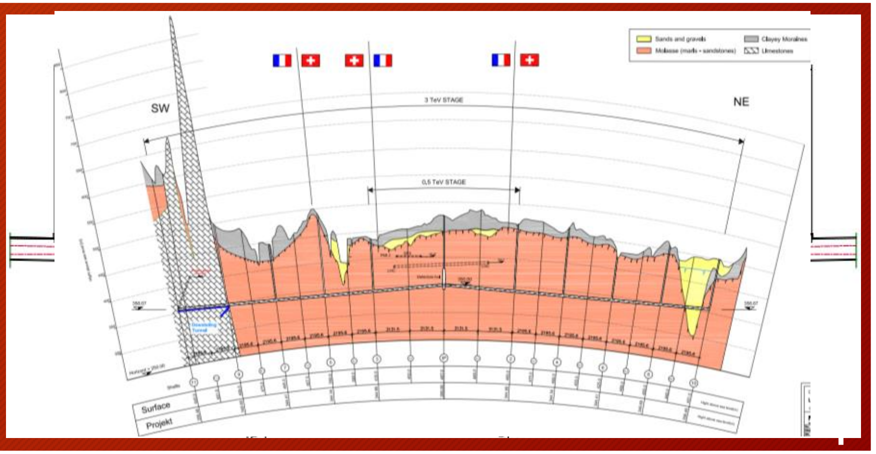
- Two beam accelerator and beam pipes
- Transport and safe walkway
- Air, water and electrical supplies
- Ancillary cables and ducts.



Central Injection Complex located on CERN land



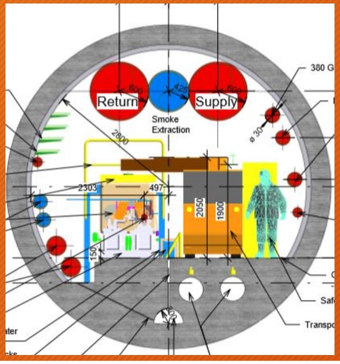
- 2 Independent Detector Caverns.
- Depth ranging from 100m to 150m along majority of length.

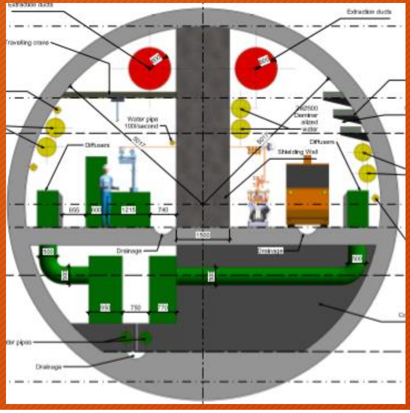


Current Status – Civil Engineering

Two options are considered in the PiP for Civil Engineering:

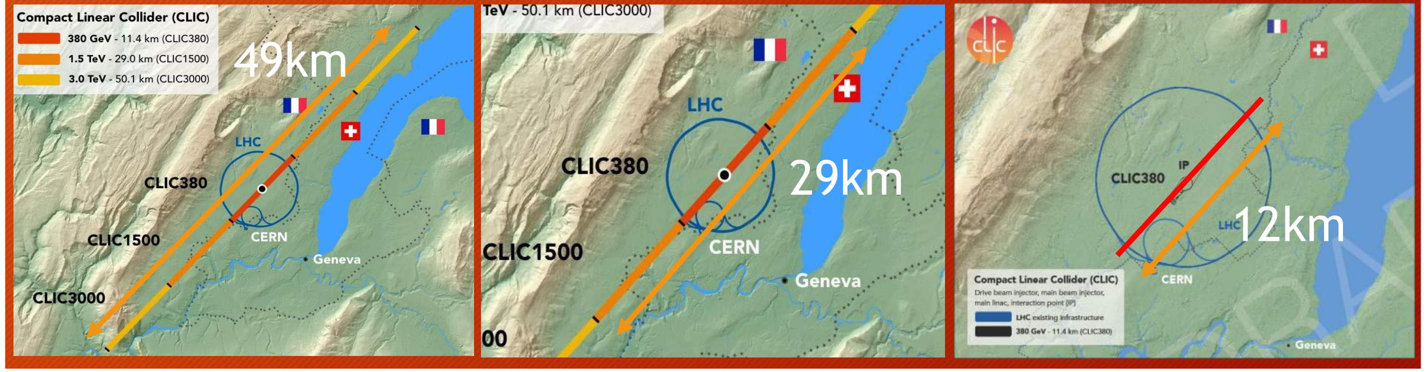
- Drive beam option with 5.6m ID.
- Klystron option with 10m ID.
  - TBM Excavation.





A **New 3 stage** Linear Collider proposed with 2 options the first energy stage of 380 GeV.

- Drive Beam options 380 GeV, 1.5 TeV and 3 TeV;
- A new Klystron option for 380 GeV.

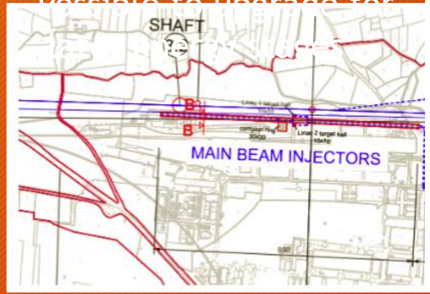


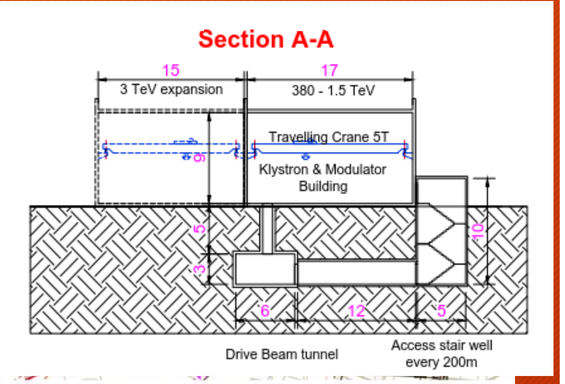
Surface sites optimised for 380 GeV DB Option:

- Reduced drive beam building.
- Possible to upgrade for

Surface sites optimised for 380 GeV - Klystron Option:

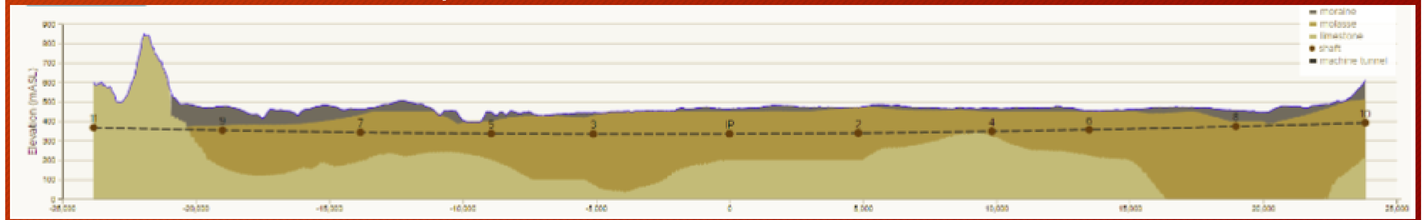
- Klystron injection complex injection facility.





A **New alignment** option (using TOT) for an optimised 380 GeV machine has been proposed.

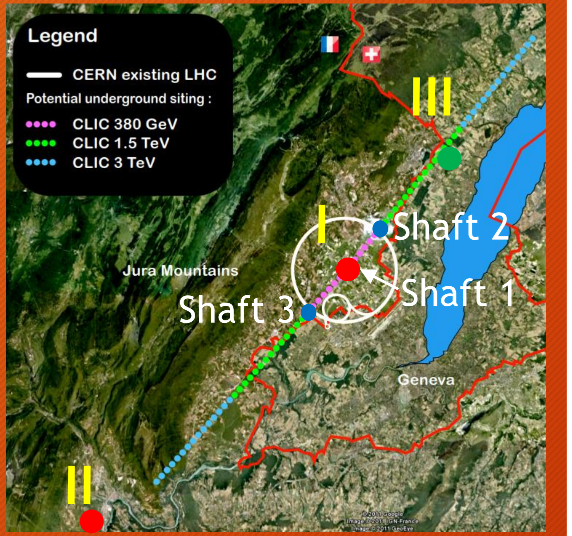
- 380 GeV machine with easy upgrade possibilities.
- Reduced overall shaft depth.



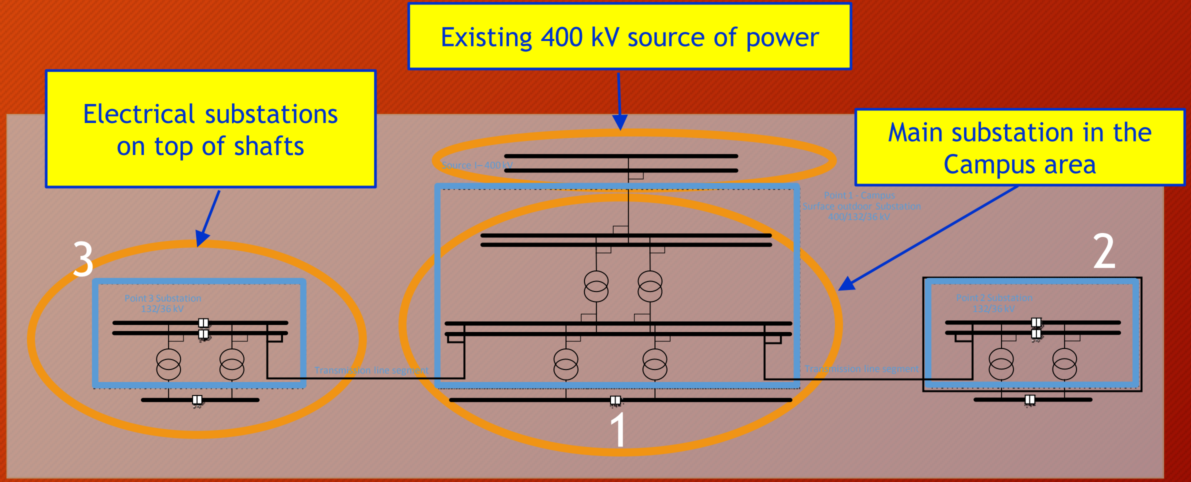
Current Status – Electrical Infrastructure

Electrical Power Supplies for CLIC 380 GeV – 3 TeV:

- Two 400kV supplies located at point I and II in France.
- One 230kV supply located at point III in Switzerland
- Necessary power requirements for CLIC are already available – no upgrades of the European grid required.



- Power supplied from the 400kV European grid to the main campus substation
- Main campus substation connects to points 2 & 3 through a 135kV transmission line



The necessary power supply for each of the four CLIC configurations is available, therefore, no upgrade or extension of the European Grid is required.

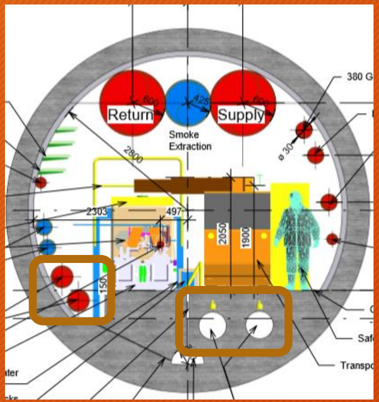
Current – Cooling and Ventilation

Air Conditioning

- 2 AHUs required per alcove (one for each side of the sector)
- Supply and extraction ducts in the tunnel
- Ambient temperature of the tunnel set at 28 degrees

Cooling Water Circuits:

- Chilled water for the AHUs
- Demineralized water for the accelerator
- Demineralized water for the remaining equipment



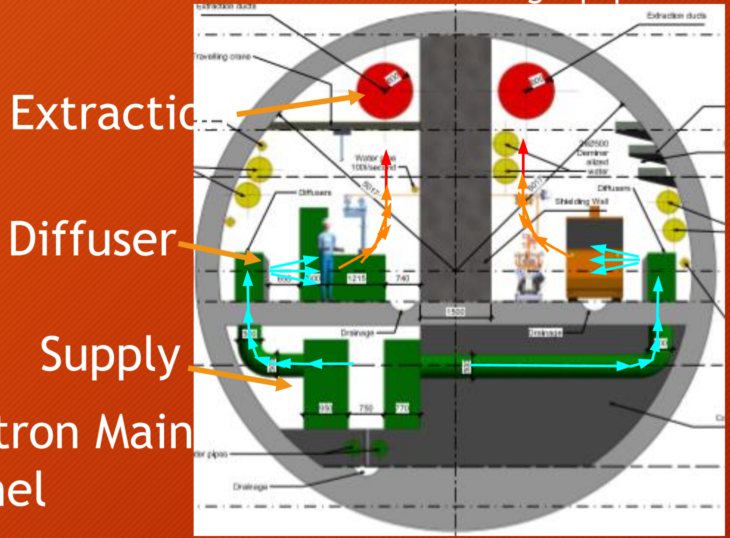
DB Main Tunnel

Air Conditioning

- Air is supplied and extracted via diffusers and extraction ducts respectively
- Air handling units cool air before driving it to the diffusers
- Ambient temperature of the tunnel set at 28 degrees

Cooling Water Circuits :

- Chilled water for the AHUs
- Demineralized water for the accelerator and klystrons
- Demineralized water for the remaining equipment

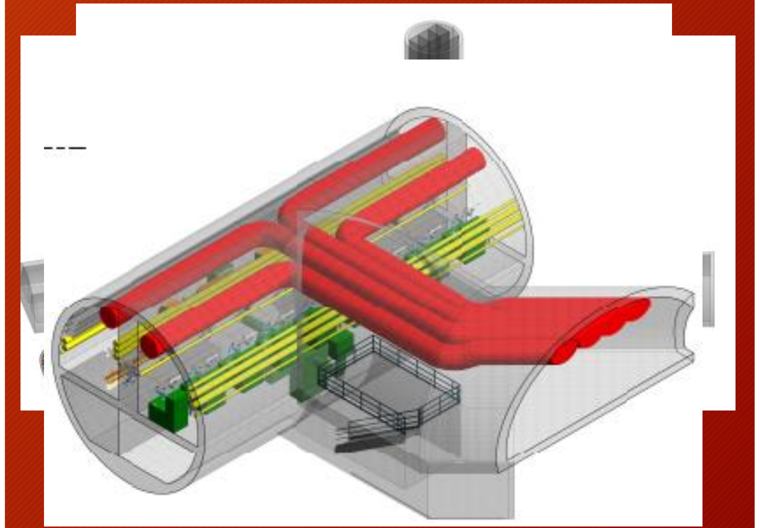


Klystron Main Tunnel

Integration with Alcoves

CV ducts to enter and exit the UTRAs and UTRCs every 878m

- Simple for the DB option
- Must pass through the shielding wall for the Klystron option



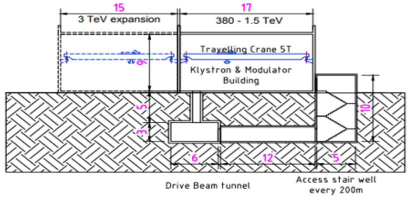
- Smoke extraction to be integrated into current duct system.

Current Status – Transport and Handling

Significant changes in the drive beam option:

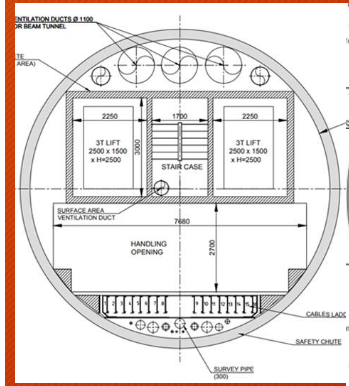
- Shaft design (2 lifts now)
- No. of transported modules.
- Integration of Transport and DB Injector building
- Cranes for surface buildings

Building Type:	Crane load capacity (tonnes)
• Detector Assembly	2x80 (CMS approach) + strand jacks
• Cooling Tower and Pump Station	3.2
• Cooling and Ventilation	20
• Cryogenic Warm compressor	20
• Cryogenic Surface Cold Box	20
• Workshop	10
• Central Area Machine Cooling Towers	5
• Shaft Access	20
• *Drive Beam Injectors*	*5x5 for 380 GeV*

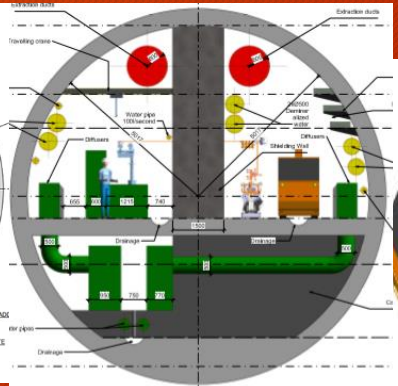


Transport requirements and updates for the Klystron design:

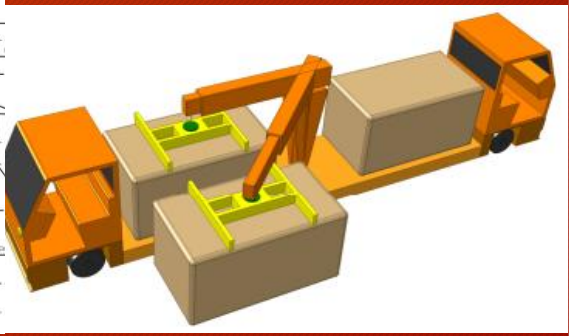
- Main tunnel transportation methods – bespoke transport vehicle for modules.
- Installation of transported Accelerating structure, Lifting arm of vehicle
- Transport options for maintenance of klystrons, crane or standard vehicles?
- Cranes for surface buildings



Shaft



Klystron Main Tunnel



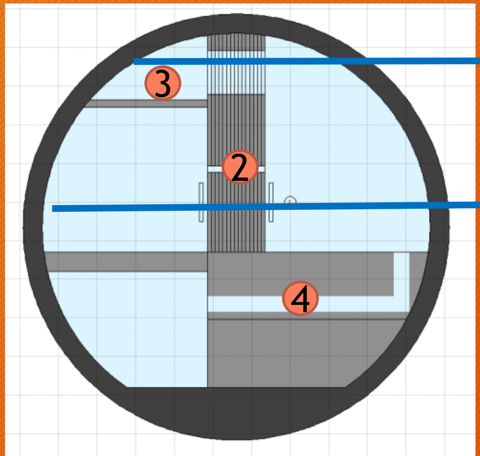
Next Steps

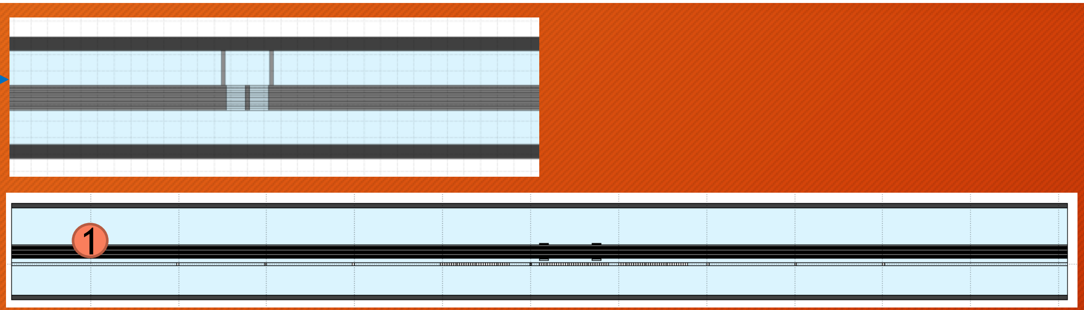
- Study machine and solenoid installation sequence for the Klystron option.
- Continuously update the equipment tables for the Klystron and DB options.
- Produce a complete list of all the buildings that require cranes.

Concerns

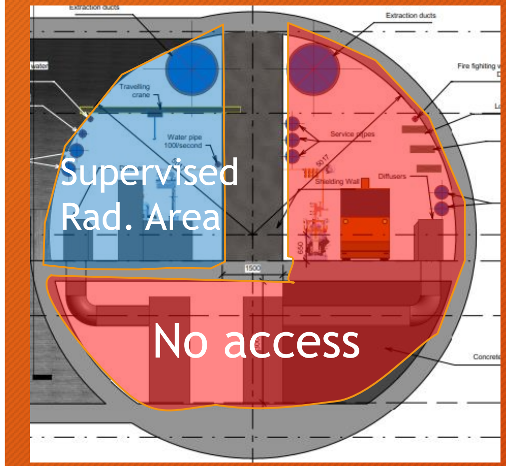
- Space constraints in the klystron option – specifically the klystron side of the tunnel

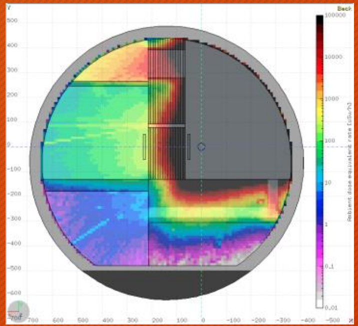
Current Status – Radiation Protection

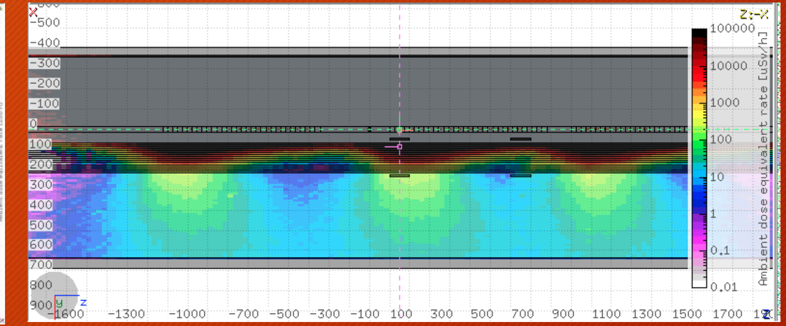




- Klystron option tunnel with separation wall simulated with FLUKA for RF conditioning with access possible in the klystron tunnel
- Geometry includes: (1) 1.5m shielding wall (2) RF wave guides ducts through the shielding wall, (3) ventilation duct crossing, (4) interleaved diffuser ducts in the tunnel floor
- Radiation source term: Dark current in RF structures. e^- energy distribution up to 600 MeV and current scaled to 4 modules (32 structures)





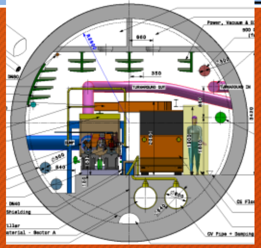
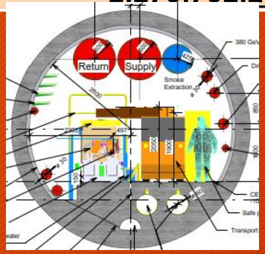
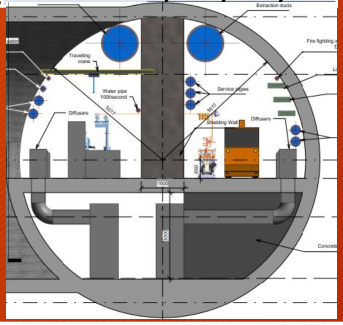


Conclusions

- Ventilation ducts need to be encased by shielding to reduce radiation streaming into the klystron tunnel
- The shielding wall is insufficient to meet design objective with the considered source term and geometry, even with heavy concrete (dose rate dominated by neutrons)
- Potential mitigation measures and further study:
  - Remove too conservative source term assumptions or adding constraints on RF operation
  - Optimise concrete composition
  - Increase wall thickness

Cost Estimate – Civil Engineering

	CDR 500 GeV (CHF)	New 380 GeV Drive Beam	Klystron 380 GeV TBM 10m
Civil Engineering	1,454,705,119	1,289,065,552	1,454,482,452
Electrical Infrastructure	303,253,39	272,001,000	272,001,000
Survey and Alignment	28,182,113	180,642,030	134,006,879
Cooling and Ventilation	459,010,252	Unknown	Unknown
Transport and Installation	93,264,733	51,400,000	51,400,000
Safety Systems	18,583,411	Unknown	Unknown
Total:	**2,356,999,018**	**2,270,702,245**	**2,389,483,994**

Drive Beam Uncertainties:

1. Shielding wall cost within the Caverns needs to be added to total Cost.
2. CV Costs still to be submitted – early indication is the difference is not too great.

Klystron Uncertainties:

1. Shielding wall separating the tunnel is based on ILC and could change (currently estimated at 30m Euros).
2. An update will be required to include the access points at each UTRC for the services compartment. (could be significant cost increase)
3. CV Costs still to be included, early indication is the difference is not too great.

Project Implementation Plan Summary

Chapter	Discipline	Pages	Comments	Responsible person	PiP Status		Cost Status	
CEIS								
	Civ. Eng	5	Pages increased to 5 for CE	John Osborne/Matt Stuart	Completed	☺☺	First Estimate	☺
	Electicity supply	3		Davide Bozzini	Completed	☺☺	First Estimate	☺
	CV	3		Mauro Nonis	Completed	☺☺	Not Received	☹
	Transport and Installation	3		Ingo Ruehl/Michael Czech	Completed	☺☺	First Estimate	☺
	Safety systems	3	incl. enviroment and access	Simon Marsh	Completed	☺☺	First Estimate	☺
	Radiation studies	3		Markus Widorski	Completed	☺☺	**N/A**	
	~~Cryo~~	3	~~in case of SC solenoid, check~~	~~Dimitri Delikaris~~	~~NA~~		~~N/A~~	

Remarks

1. Final draft by the 01st of November 2018 to allow executive summary to be prepared.
2. Final ESU submission by the 18th of December 2018.
3. External Cost Review on the 06th of November.

Conclusion

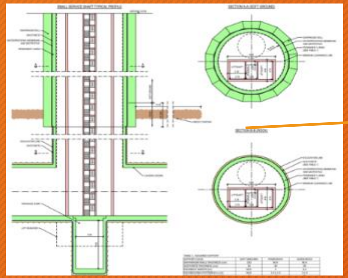
Next Steps CEIS Working Group

- Integration studies for the C&V and tunnel alcoves to be completed.
- Cooling and Ventilation cost studies to be completed.
- RP Studies to be concluded to understand the protection requirements for CLIC
- Final update of figures and tables for the PiP required

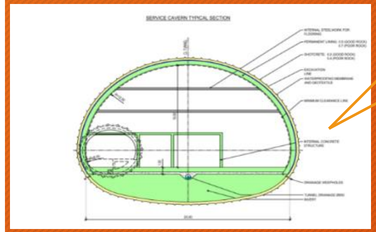
Remarks and upcoming milestones for 2018

1. Final draft by the 01st of November to allow executive summary to be prepared.
2. Final ESU submission by the 18th of December.
3. External Cost Review on the 06th of November.
4. Final CEIS Meeting of the year on the 09th of November.

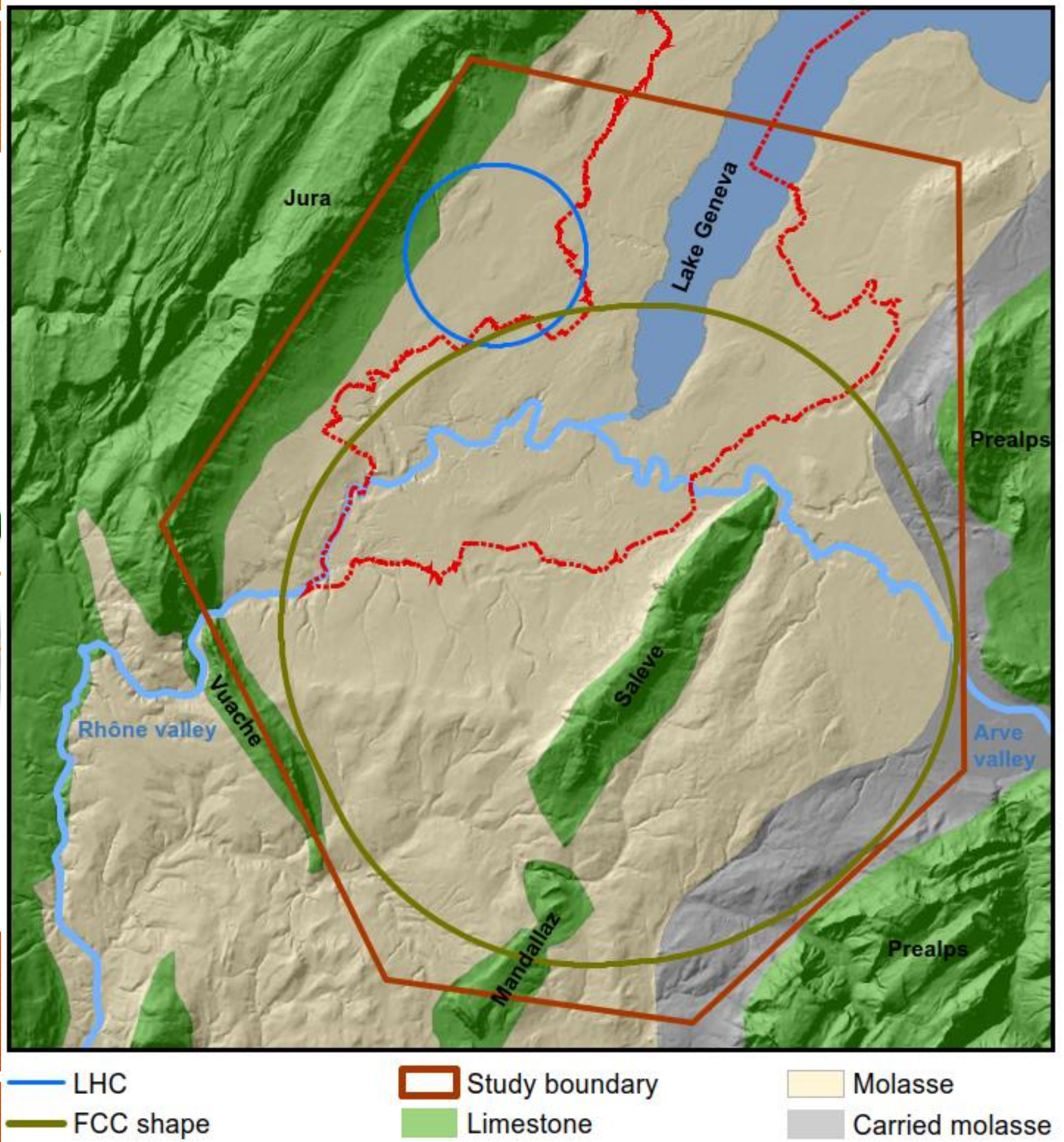
Scope of FCC-hh

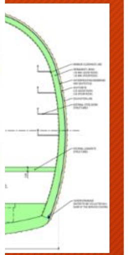


Shafts:
Experimental Shafts:
15 m dia. + 10 m dia.
Service shafts:12 m dia.
Magnet delivery shaft:18 m

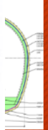


Service Caverns
- 25 m x 15 m x 100 m





erimental
35 m x 66m

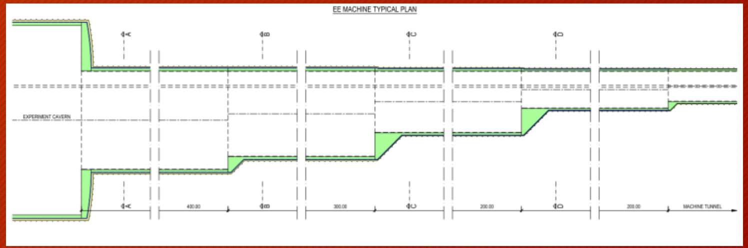


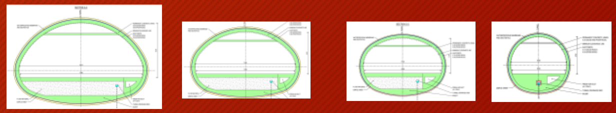
verns
10 m x 50 m

e tunnel
s tunnels

FCC-ee

- Would be constructed at the same time as FCC-hh
- Infrastructure must be able to accommodate both machines.
- Enlargements required at experiment points A and G.





Implementation - new footprint baseline

Alignment | Shafts | Query

Choose alignment option

V4variation_v2017-2

Tunnel elevation at centre:322mASL

Grad. Params

Azimuth (°): -23.5

Slope Angle x-x(%): 0.3

Slope Angle y-y(%): 0.08

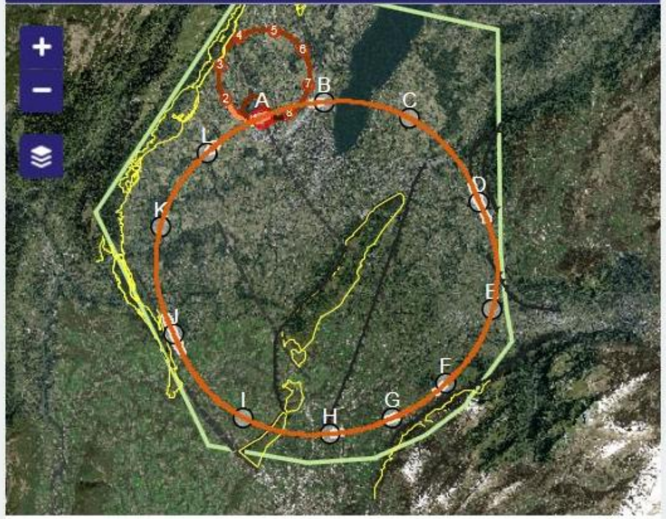
LOAD | SAVE | CALCULATE

Alignment centre

X: 2499941 Y: 1107760

	CP 1		CP 2	
	Angle	Depth	Angle	Depth
LHC	37°	49m	-40°	83m
SPS		121m		126m
TI2		121m		126m
TI8		51m		118m

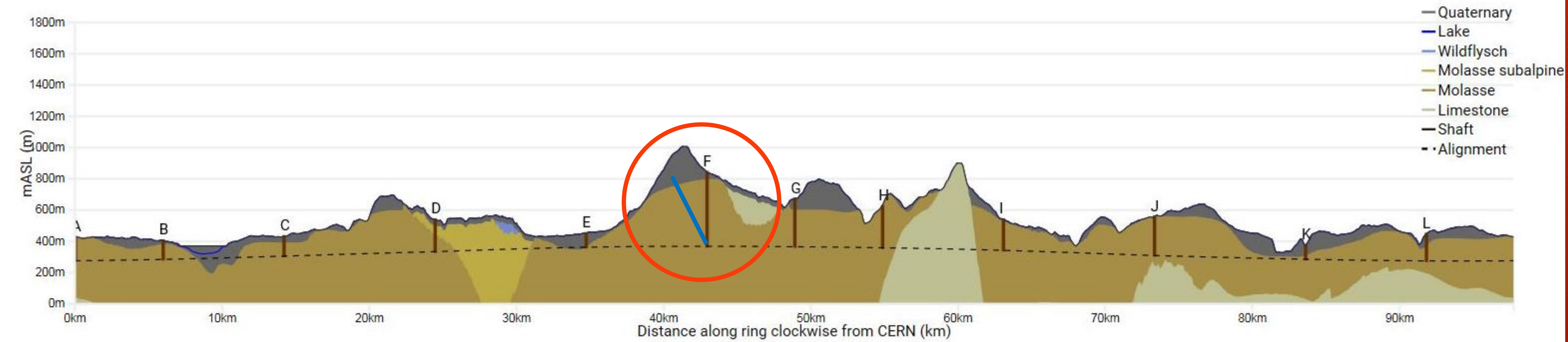
Alignment Location



Geology Intersected by Shafts | Shaft Depths

Point	Shaft Depth (m) Actual	Molasse SA	Wildflysch	Geology (m) Quaternary	Molasse	Urgonian	Limestone
A	152	0	0	0	152	0	0
B	121	0	0	26	95	0	0
C	127	0	0	44	83	0	0
D	205	66	0	40	100	0	0
E	89	0	0	89	0	0	0
F	476	0	0	49	427	0	0
G	307	0	0	73	234	0	0
H	266	0	0	0	266	0	0
I	198	0	0	11	187	0	0
J	248	0	0	1	247	0	0
K	88	0	0	70	18	0	0
L	172	0	0	89	83	0	0
Total	2449	66	0	492	1892	0	0

Alignment Profile



Geology Intersected by Tunnel | Geology Intersected by Section

84.6% | 5.2% | 5.5% | 4.7%

Optimisation in view of accessibility surface points, tunneling rock type, shaft depth, etc.

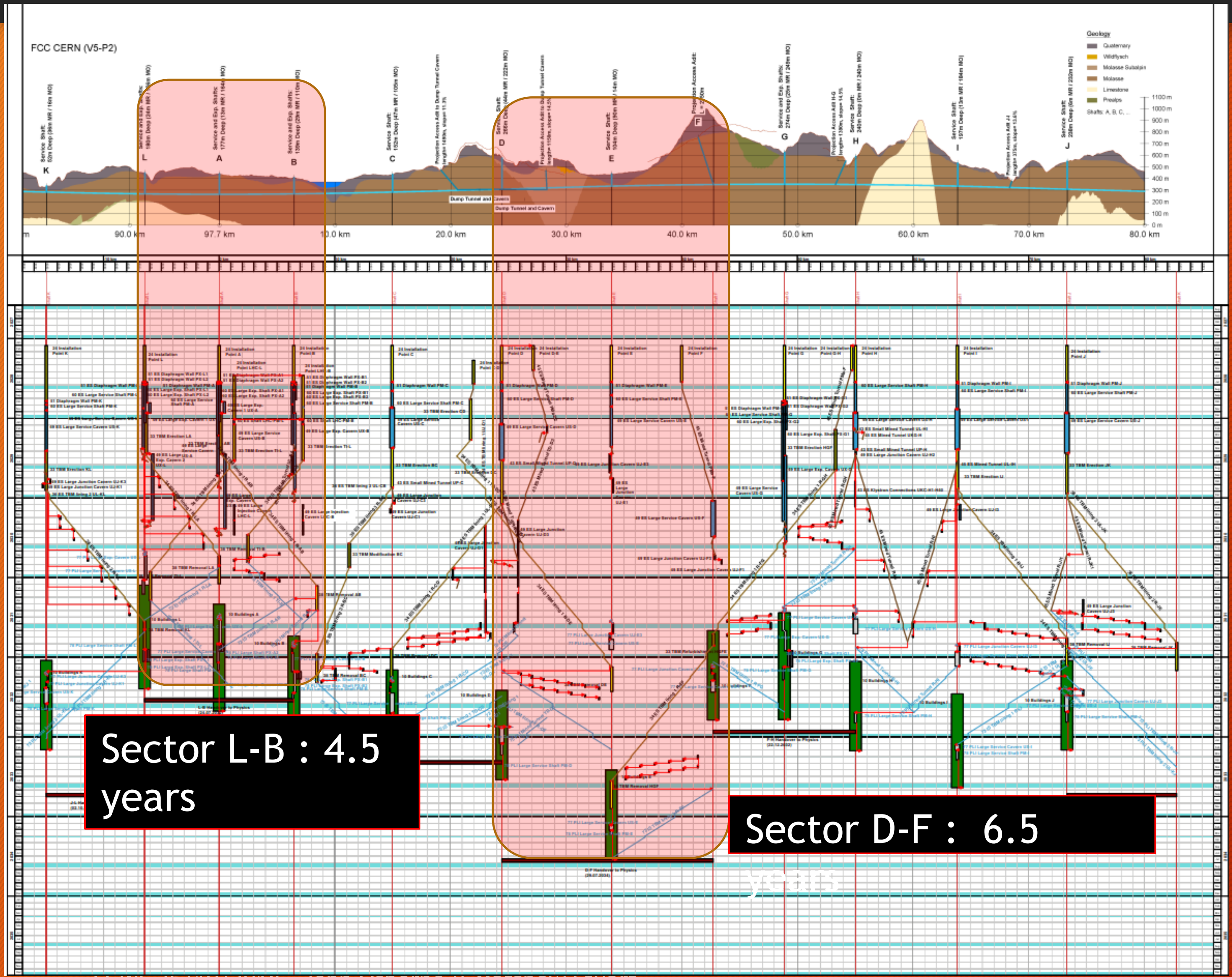
Tunneling

- Molasse 90%, Limestone 5%, Moraines 5%

Shallow implementation

- ~ 30 m below lakebed
- Reduction of shaft length and technical installations
- One very deep shaft **F** (RF or collimation), alternatives being studied - inclined access tunnel.

Schedule hh and ee??

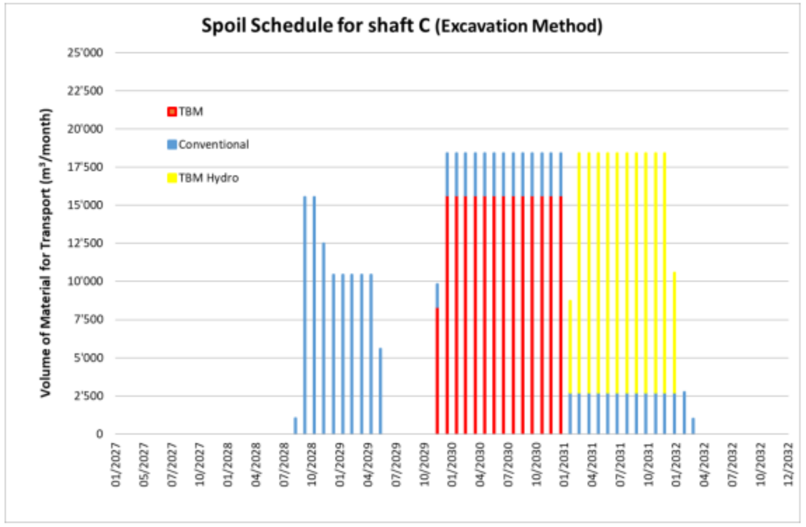


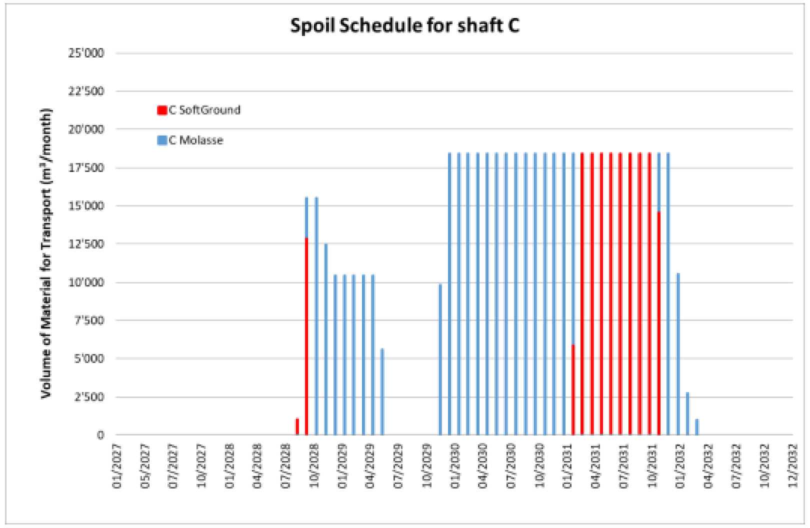
- CE and schedule studies with consultants
- First sectors can be available after 4.5 to 5 years for Technical Infrastructure install.
- Total CE duration about 7 years
- Next steps:
  - combination with logistics considerations for TI and machine installation for overall schedule optimization.
  - FCC-ee schedule to be updated – impact on overall schedule TBC.

Spoil Management Study

- In the Process of launching a study into disposal/re-use of 9 million cubic metres of spoil anticipated from FCC excavation.
- *PhD student from Montan university Leoben/Austria, in collaboration with CETU.*

Extraction Site	Volume (m³)			
	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
Total Spoil Volume	**366,500**	**261,422**	**8'370'487**	**8'998'409**



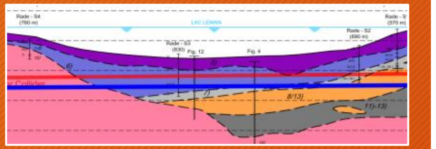


- Main spoil volume consists of molasse containing different rock types ranging from: weathered molasse, weak, soft and medium marls, soft, hard and V. hard sandstone.
- First sample has been taken from HL-LHC construction site "point 1" to be analysed chemically/mineralogically, also plan to analyse it petrophysically;
- PhD thesis focuses on re-use and re-evaluation of molasse within a legal and environmental framework of Swiss/Genéve and French authorities.
- Study for re-use of molasse not only applicable for FCC but all worldwide tunnelling projects
- Development of online analysis tool on site (conveyer belt) to separate material via different methods e.g. optical or chemical methods.
- Research mainly conducted in Austria (Koralm-Tunnel, Semmering-Base-Tunnel) and Switzerland (Gotthard-Base-Tunnel); HOWEVER: for different material!

Civil Engineering study progress 2017/18

Alignment update following geological review of key areas:
- Lake crossing
- Arve and Rhone Valleys

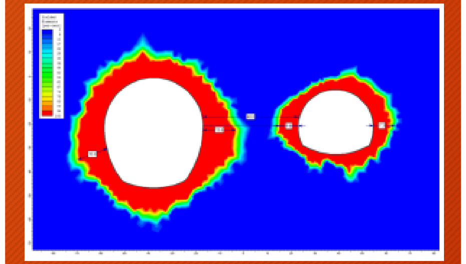
Led to the lowering of the alignment by 30 m.



Phase 3 of cost and schedule study launched.

- Refinement of results from previous phases
- Produce a cost and schedule estimate that is compatible with the CDR baseline.

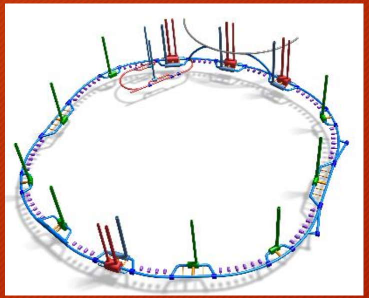
Design development with integration, including study to investigate feasibility of interaction region layout.



- Cost and schedule round up for all 3 machines:

FCC-hh, FCC-ee and FCC-eh

- CDR writing



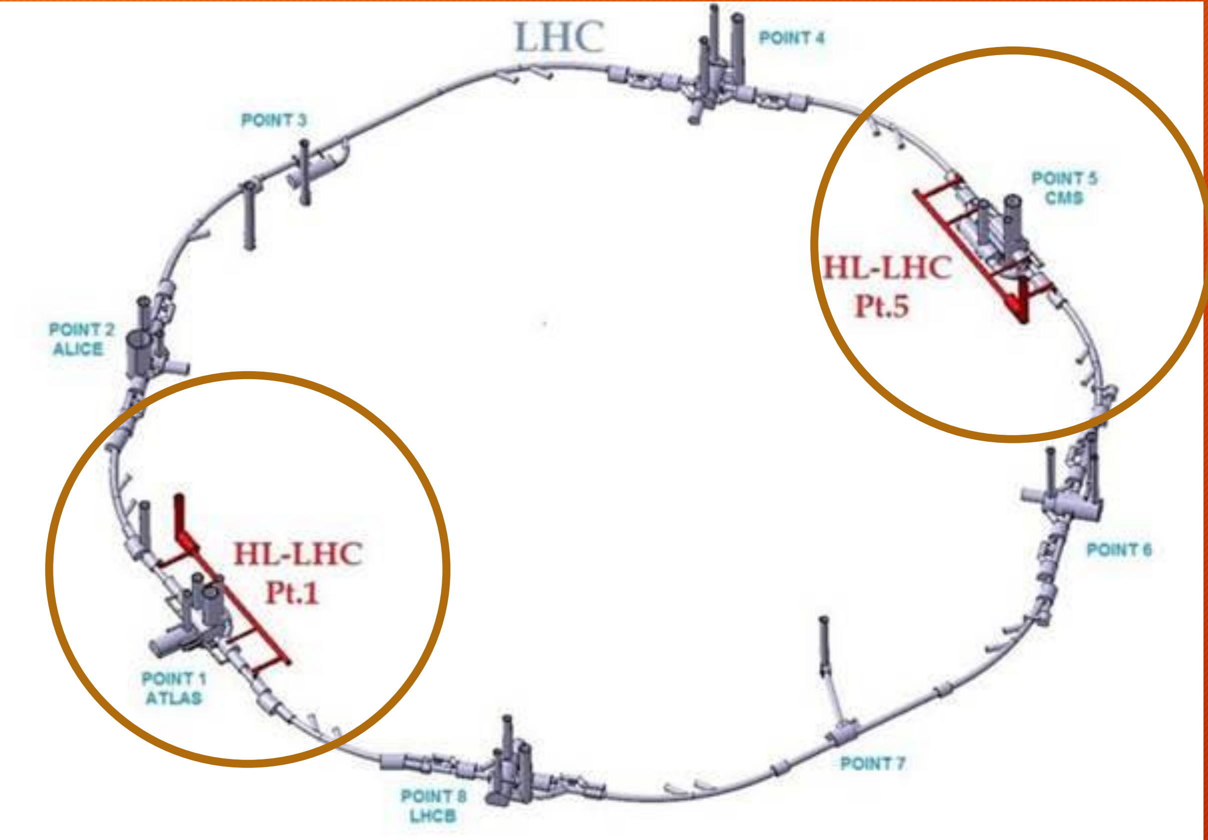
Ongoing work:

- Surface site investigation
- Spoil management study
- Site investigation planning
- HE-LHC feasibility and cost
- Transfer line design

August 2017 | September 2017 | February 2017 | March 2018 | Ongoing

John Osborne & Jo Stanyard
SMB-SE-FAS

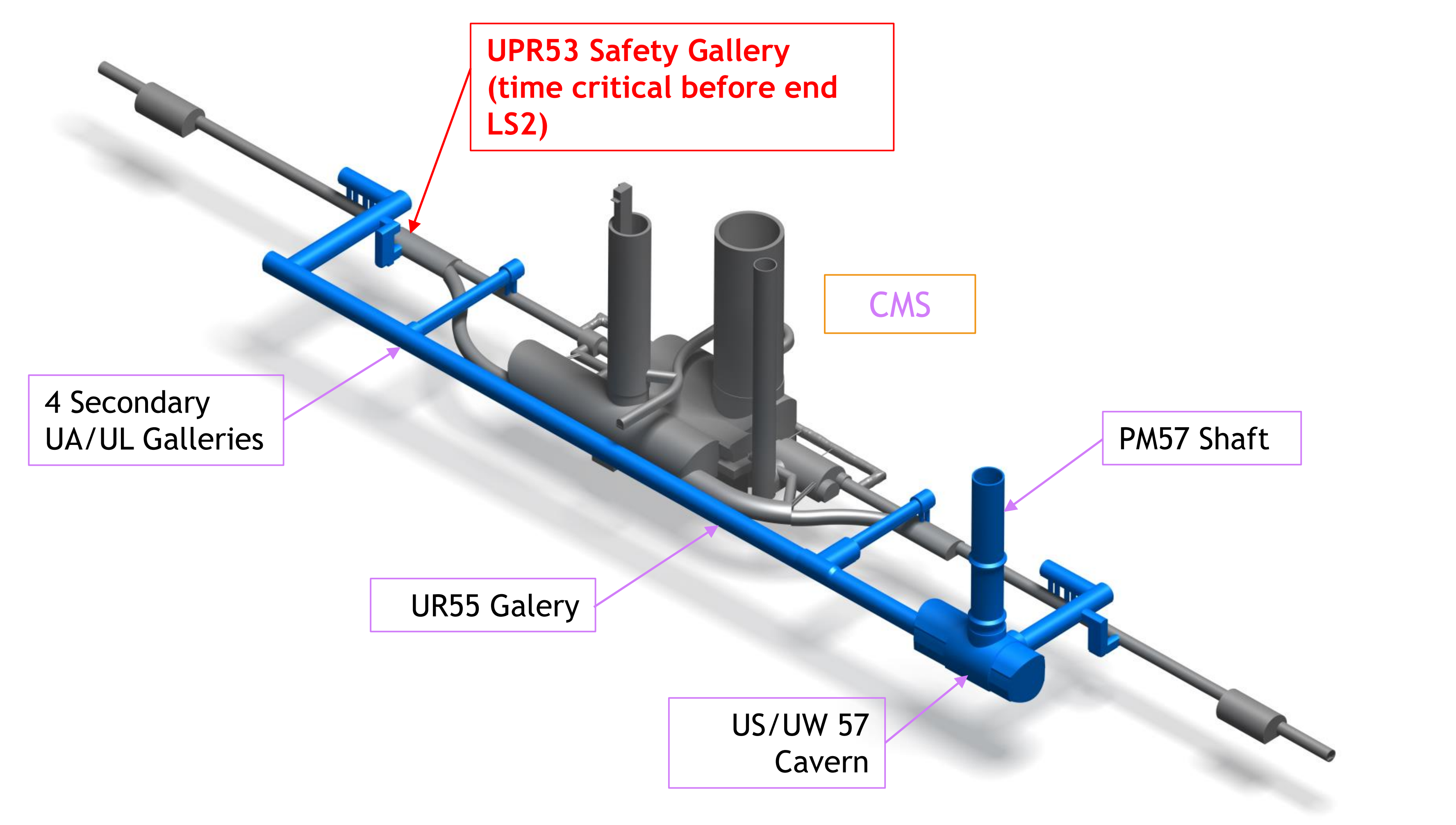
Hi-Lumi upgrade



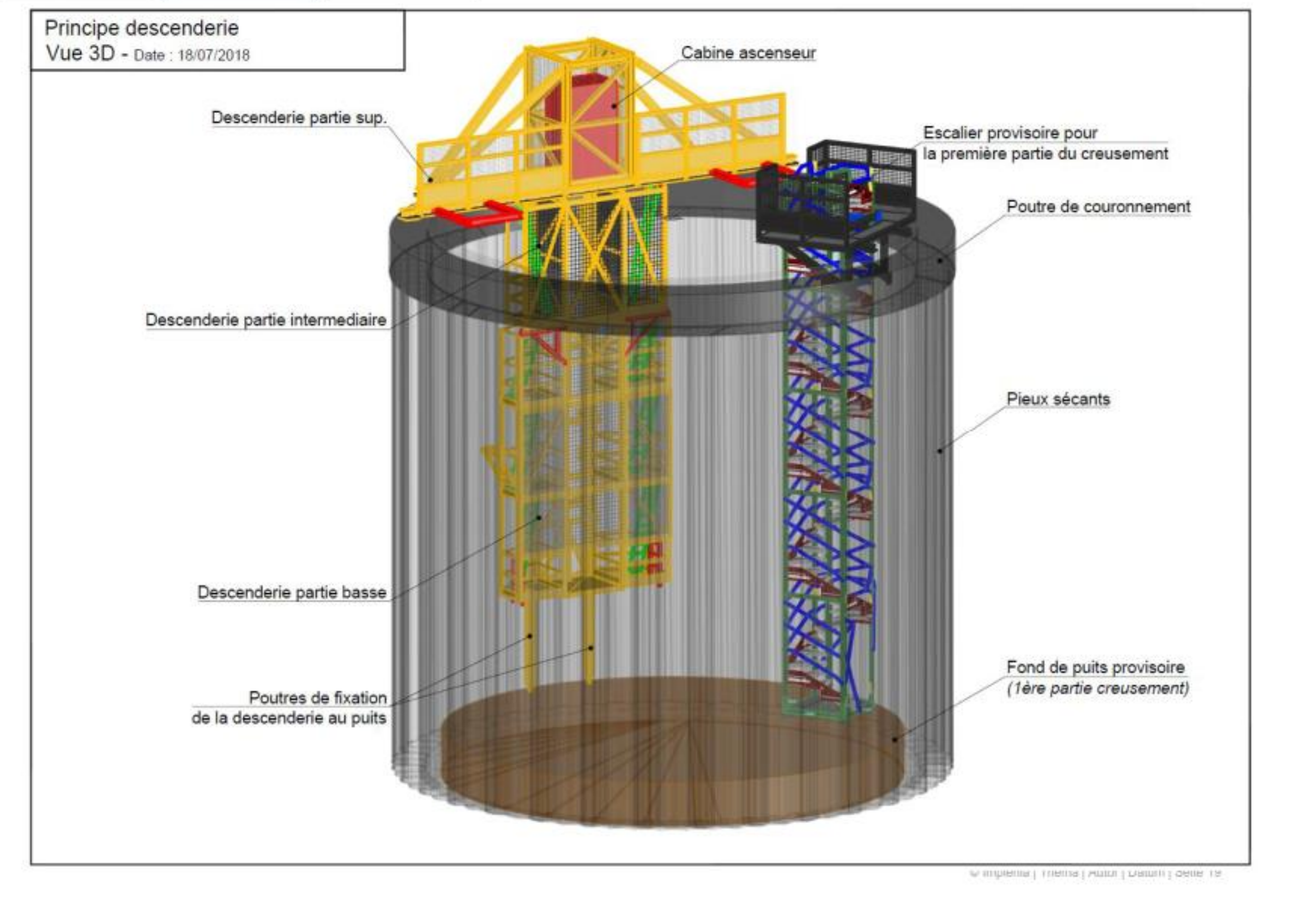
Contract

- Company: CIB Consortium Implenia Baresel
  - Origin France, Germany, Switzerland;
- Value of the contract: EUR 58 million
- Duration of work: 2018-2022 (54 months)
  - Underground: mid-2018 until the end of 2021;
  - Surface: early -2020 until mid-2022;

Underground Works at Point 5



Shaft Construction PM57 – 24.5m depth



- Shaft excavation during LHC operation in 2018;
- Fundamental assumptions based on outcome of measurements & simulations:
  - Diesel powered excavators & hydraulic hammers are very risky wrt vibration impact on LHC;
  - Electrically powered excavators & rotary cutter heads are much safer wrt vibration impact on LHC;
- Reality / measurements to date have shown:
  - To date majority of vibration issues caused by compactors at the surface (and not by excavators in shaft);
  - Electric excavator with hydraulic hammer (used at Point 1 since mid-August 2018) has not (yet) caused vibration issues; situation is being closely monitored …

Construction Challenges

During the construction:

- Materials from the excavations are transported to inert waste storage facilities located within 20km of the site;
- Protection of pedestrian traffic around the site (Chemin des Mouillets and Chemin du Milieu);
- Minimized noise thanks to the building that caps the well;
- Max. 70 people on site, in the long term: The new buildings will house technical installations and equipment; no permanent workstation; Circulation unchanged.

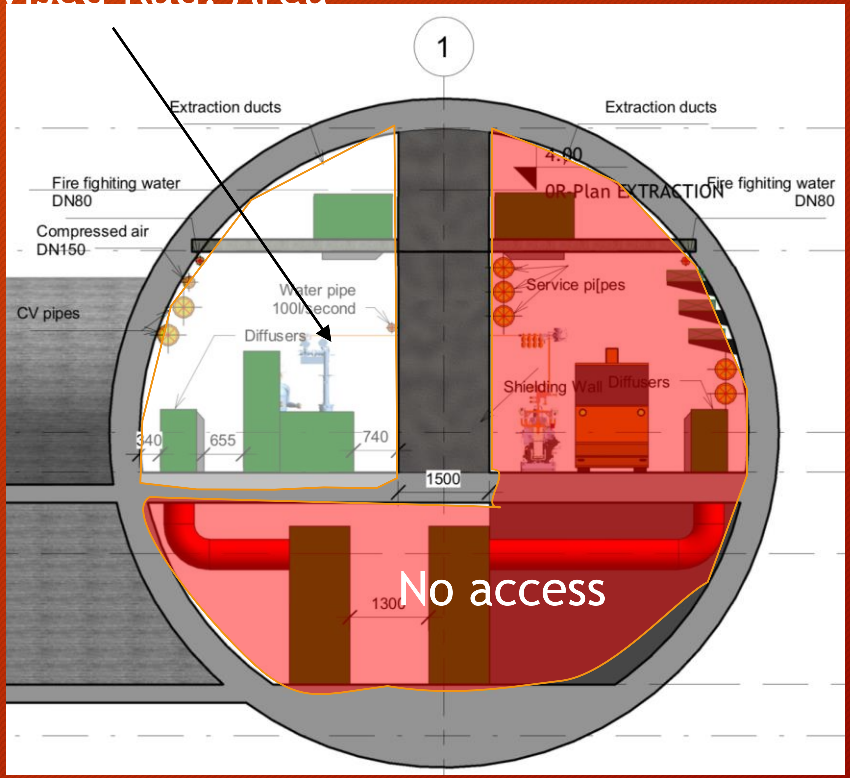
Conclusions

- Progress in 2017:
  - Obtained building permits; completed tender design;
  - Started construction design for underground structures;
  - Tendered civil engineering works at Point 1/5;
- Progress in 2018:
  - Signed construction contracts for Point 1/5;
  - Site mobilisation completed;
  - Started PM17/57 shaft excavation; (digging hard!)
- 1-Year look ahead:
  - Complete shaft & cavern excavation;
  - Complete majority of UR15/55 gallery excavation;
  - Complete construction design for surface structures.

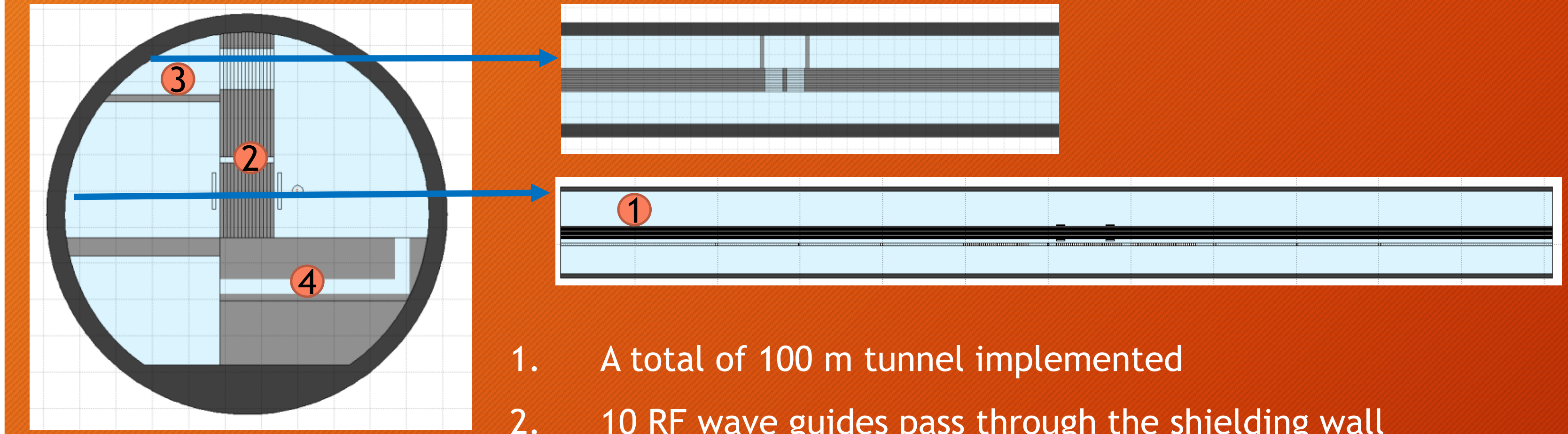
Thank You For Your Attention

Baseline

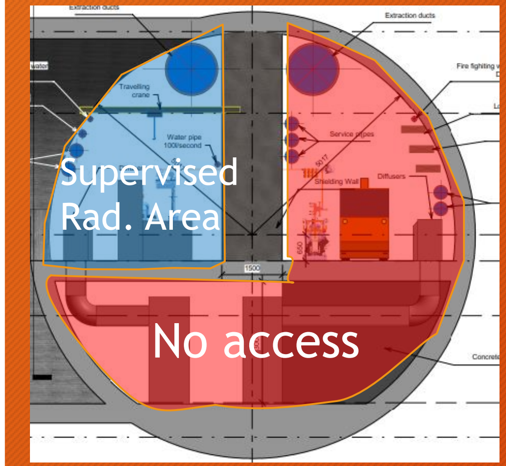
- Klystron tunnel shall remain accessible for maintenance works during conditioning of RF structures
- Design objective: Klystron tunnel classified as *Supervised Radiation Area* (max. 3 μSv/h ambient dose equivalent rate)
- Good definition of input parameters is crucial to obtain reliable output

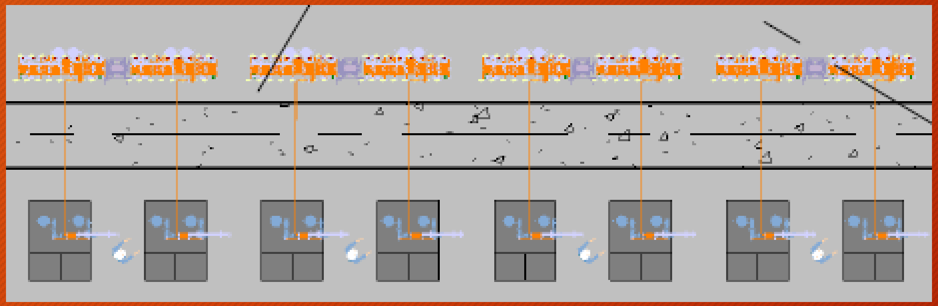


Current Status – Radiation Protection



1. A total of 100 m tunnel implemented
2. 10 RF wave guides pass through the shielding wall
3. Ventilation duct crossing, encased by 20 cm concrete
4. Diffuser ducts interleaved





Conclusions

- Ventilation ducts to be encased by shielding to reduce radiation streaming towards klystron tunnel
- The shielding wall is insufficient to meet design objective
- Potential mitigation measures or further study:
  - Remove too conservative assumptions or adding constraints on RF operation
  - Contribution from the shielding penetration is dominating → optimise concrete composition
  - Increase shielding wall thickness
  - Quantify contribution from diffusing through ducts