UPDATE ON CIVIL ENGINEERING FOR THE FCC

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PROGRESS ON CIVIL ENGINEERING FOR THE FCC

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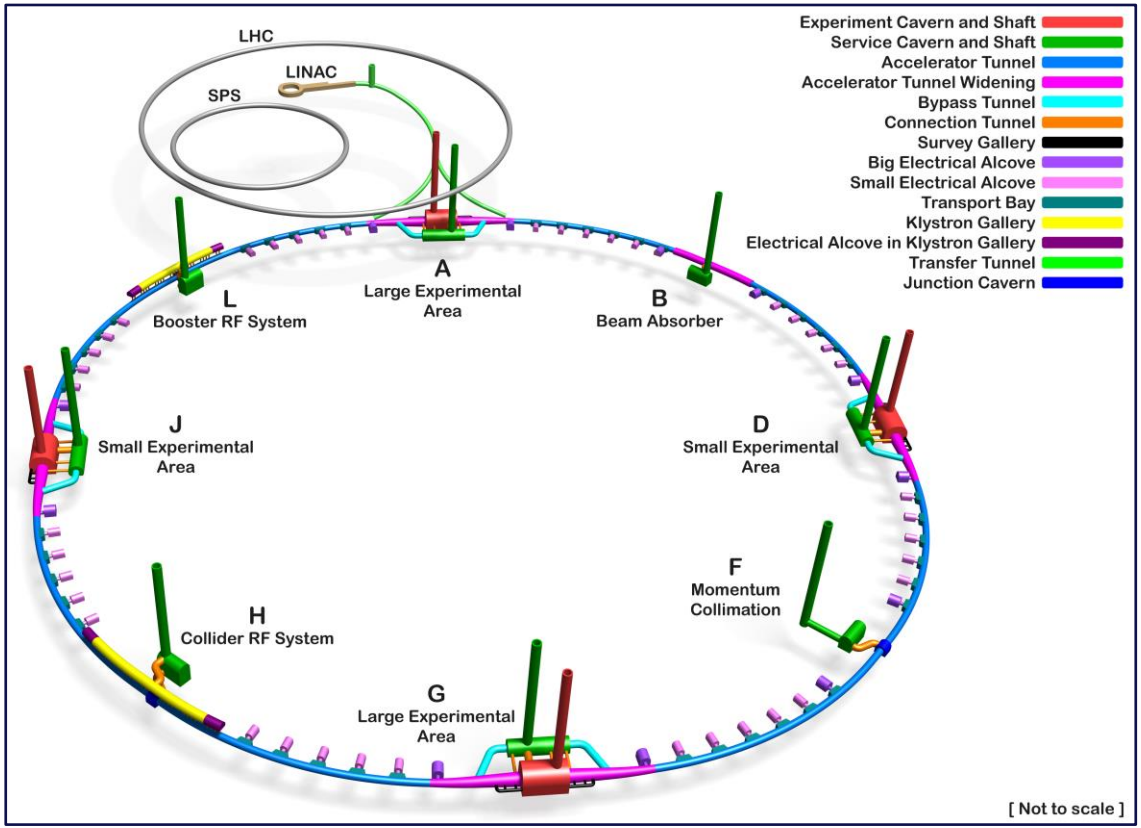
Acknowledging the contributions made by our external collaborators during 2024. SGS3, Geotech IOI, Amberg, ILF, Quantum, Rendel/Ingerop, Stone Consulting and the University of Geneva, Earth Sciences department.

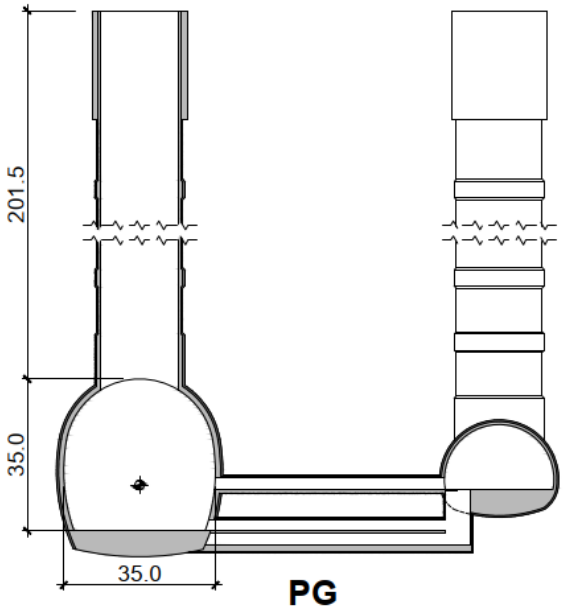
Contents

Key features of the Underground Civil Engineering Baseline

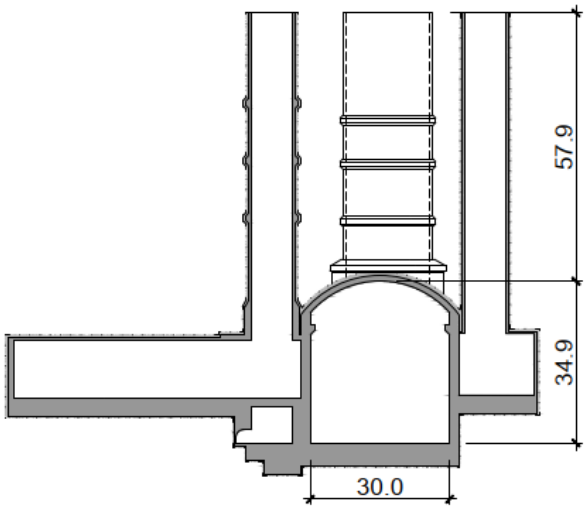
- Tunnel Circumference: 90.7 km
- Excavated vol: 6.25M m^3 (*in-situ* volume)
- Access shafts: 12
- Construction shafts: 1
- Large experiment sites: 2
- Small experiment sites: 2
- Technical sites: 4
- Deepest shaft: 400m
- Average shaft depth: 243m
- Total concrete volume: 1.9 M m^3



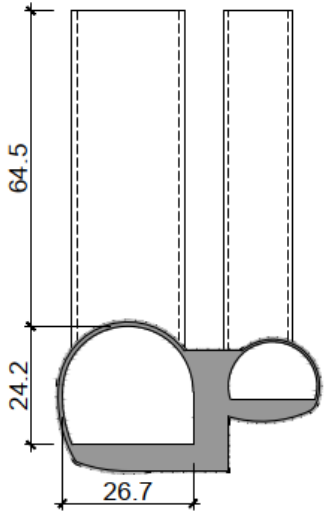
Comparison between FCC and the ATLAS/CMS Caverns



FCC



ATLAS

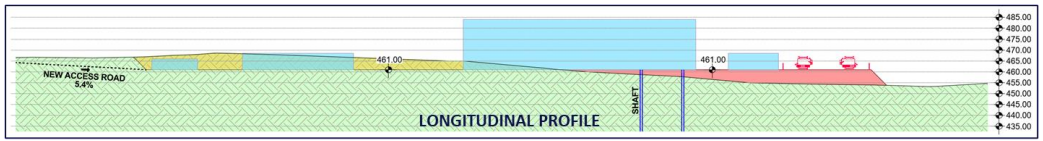


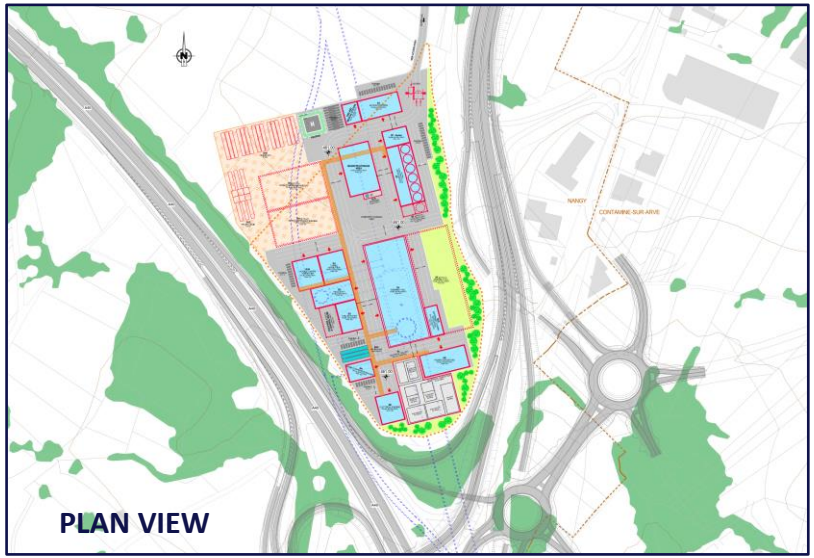
CMS

Note that although cavern dimensions are similar to FCC, in-situ ground stress is expected to be about 3 x greater
For the deepest experimental site (PJ) the depth is 250m so in-situ vertical stress will be about 6.4MPa

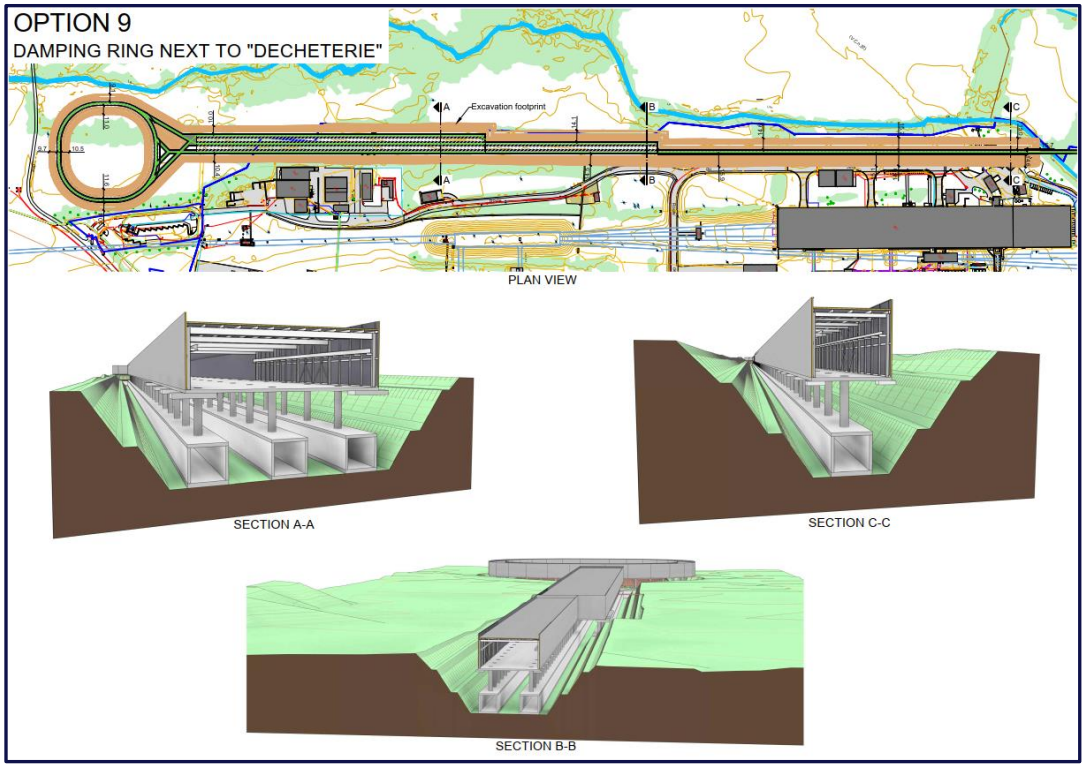
Surface Civil Engineering Baseline

- Preliminary plan views and sections of all eight surface sites have been prepared at CERN based on the requirements study led by the integration team and target land plots identified by the territorial implementation team.
- The dimensions and function of the buildings are to a large extent based on CERNs previous experience as detailed engineering studies for most interfacing systems have not yet been carried out.
- The plans, drawings and specifications have been prepared primarily for the purpose of cost estimation, this being done by an external contractor.

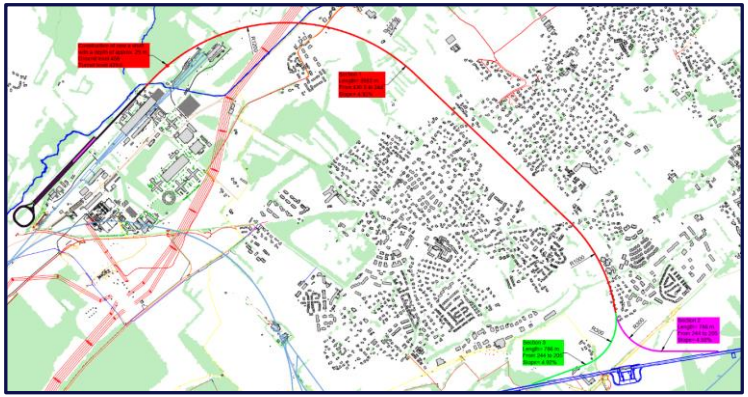




Injection Complex Baseline



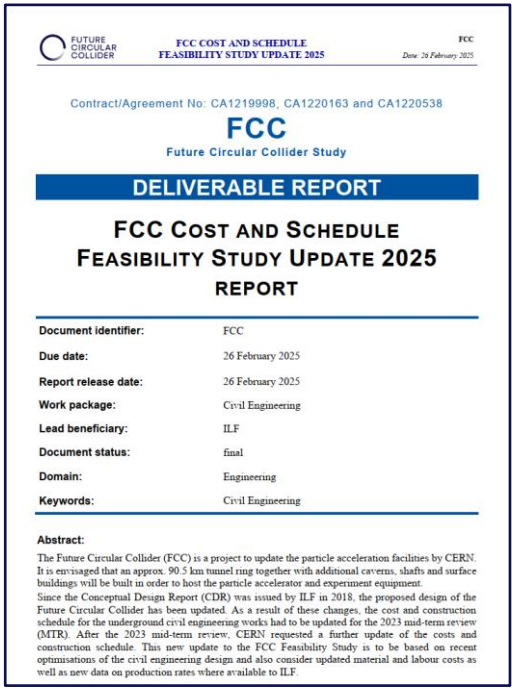
- Preliminary layout that fits within current Prevessin fence line.
- Contracts for hydrological and geological assessments are about to be launched
- Initial state analysis to be undertaken (ATS with HSE).
- Studies ongoing to confirm overall footprint and main CE requirements (SY-ABT/PSI/CHART)



Construction Schedule/Cost

- External consultant ILF (AT/CH) were contracted to update the schedule and cost estimate for the underground works for the baseline civil engineering as of October 2024.

- A detailed schedule was built up using assumed construction methodology and sequencing as well as ILF data on construction performance (advance rates etc.) from numerous underground projects.
- The update includes the the CERN decision to drive 2 TBMs from four of the eight sites and also included the removal of the constraint that tunnel sectors must be handed over to CERN only when fully complete over their full 11km length.
- Unit costs were updated and advance rates of tunnel excavation reduced to account from industry feedback given to CERN.
- Phased handover of tunnel sectors now gives a wider spread on sector delivery dates but gives earlier access to the finished tunnel from the technical sites.



FUTURE CIRCULAR COLLIDER

FCC COST AND SCHEDULE FEASIBILITY STUDY UPDATE 2025

FCC

Date: 26 February 2025

Contract/Agreement No: CA1219998, CA1220163 and CA1220538

FCC

Future Circular Collider Study

DELIVERABLE REPORT

FCC COST AND SCHEDULE FEASIBILITY STUDY UPDATE 2025 REPORT

Document identifier:	FCC
Due date:	26 February 2025
Report release date:	26 February 2025
Work package:	Civil Engineering
Lead beneficiary:	ILF
Document status:	final
Domain:	Engineering
Keywords:	Civil Engineering

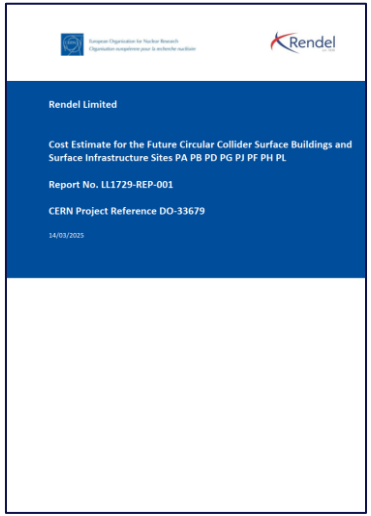
Abstract:

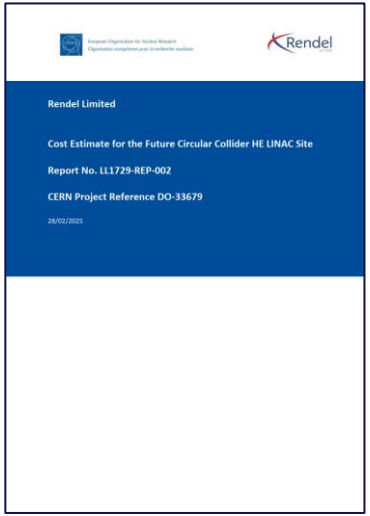
The Future Circular Collider (FCC) is a project to update the particle acceleration facilities by CERN. It is envisaged that an approx. 90.5 km tunnel ring together with additional caverns, shafts and surface buildings will be built in order to host the particle accelerator and experiment equipment.

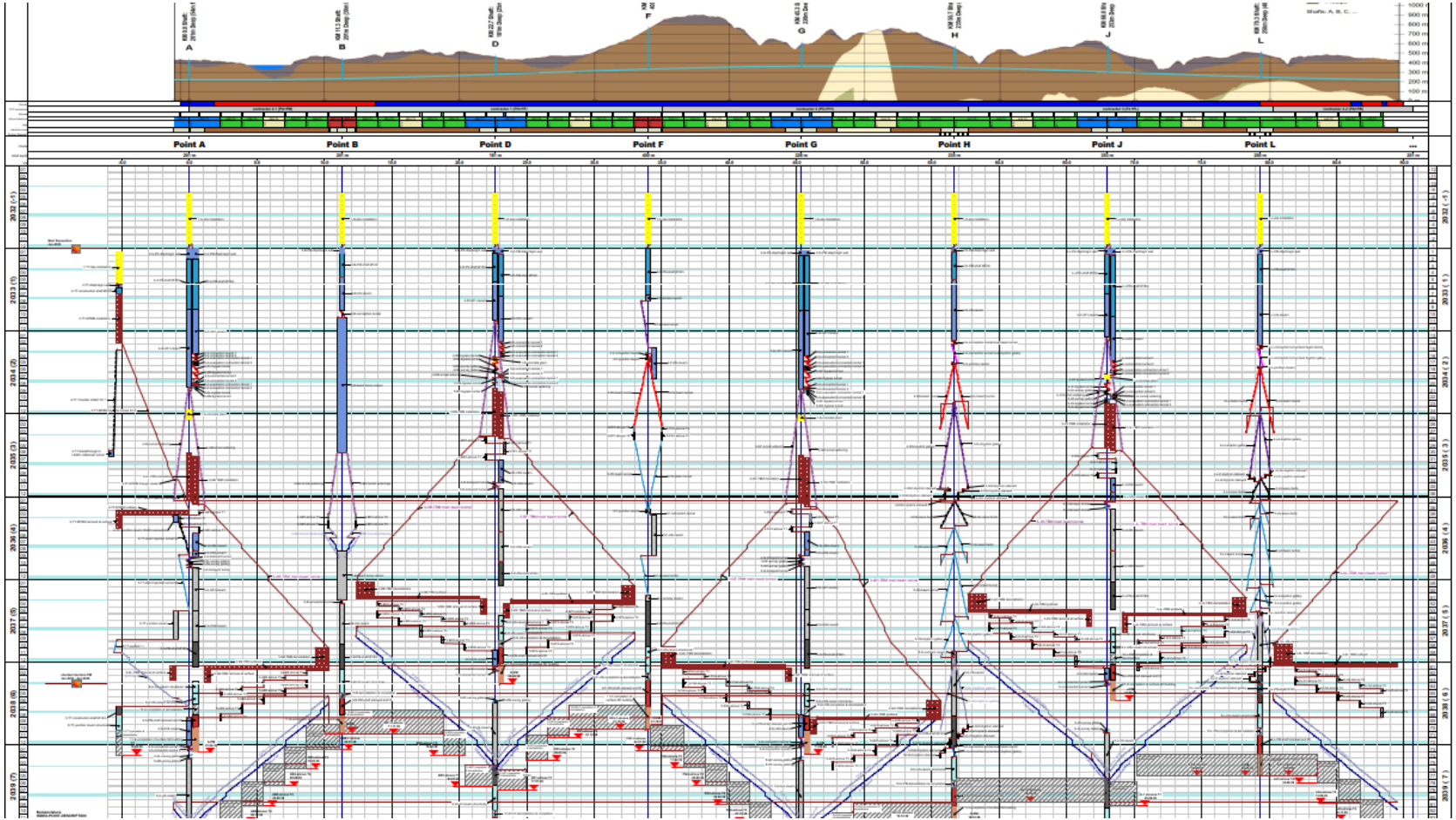
Since the Conceptual Design Report (CDR) was issued by ILF in 2018, the proposed design of the Future Circular Collider has been updated. As a result of these changes, the cost and construction schedule for the underground civil engineering works had to be updated for the 2023 mid-term review (MTR). After the 2023 mid-term review, CERN requested a further update of the costs and construction schedule. This new update to the FCC Feasibility Study is to be based on recent optimisations of the civil engineering design and also consider updated material and labour costs as well as new data on production rates where available to ILF.

Construction Schedule/Cost

- For the surface works, CERN contracted with a UK/FR/CH consortium from the Ingerop engineering group.
- CERN prepared preliminary layouts and cross-sections for each surface site as well as bills of quantities for two of the sites.
- The consultant built up cost estimates based on quantities for all buildings/infrastructure for each of the eight sites.
- The same consultant performed a similar exercise for the FCC Injector complex on the Prevessin site.
- The surface buildings make up about 12% of the civil works (by cost).
- No detailed schedule has been prepared for the surface buildings, but it is expected that most of the work will be done off the project critical path.



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Industry Feedback

1. CERN has continued to meet with key players from member state civil engineering companies.
2. Companies from AT, CH, DE, ES, FR, GB, IT, SE, have been engaged in informal discussions on technical and strategic topics.
3. Most contractors considered that the complete civil engineering scope would be too great for one company to undertake alone.
4. All contractors recognized the difficulty of working in new markets that already have mature and capable industry.
5. Most contractors flagged the benefits of so called “ early contractor involvement”
6. All contractors agreed that there is only one European TBM manufacturer capable to build machines suitable for FCC.
7. Long lead times for TBM procurement should be expected (> 1 year)

Technical Feedback

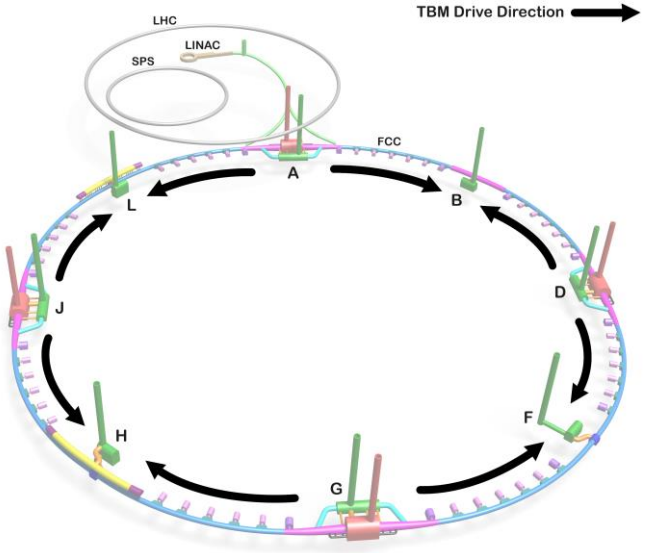
1. All of the companies considered that the underground works were feasible and well within the technological capabilities of the civil engineering industry today.
2. The long single access tunnels of about 10km was not considered to be an issue but logistics may become the critical activity. CERN commissioned specific studies on this topic.
3. Having a single shaft to access the underground works was considered a potential bottleneck given that everything coming into and out of the underground would need to pass through this shaft. CERN commissioned specific studies on this topic.
4. All contractors considered that dealing with excavated material was a major challenge and that this was a risk that the Client should directly manage in advance of the civil works. This is CERN's strategy.
5. One specific ongoing project in GB is of particular interest due to its technical similarities to FCC – Woodsmith mine tunnel.

Woodsmith Mine Tunnel

- Sedimentary rock similar in strength and variability to molasse
- 36 km using a single TBM
- Internal diameter 4.9m (FCC is 5.5m)
- One-pass segmental lining
- Average depth around 250m
- Advance rates of 20m/day
- Contractor Strabag (AT)

Contract Strategy for Construction

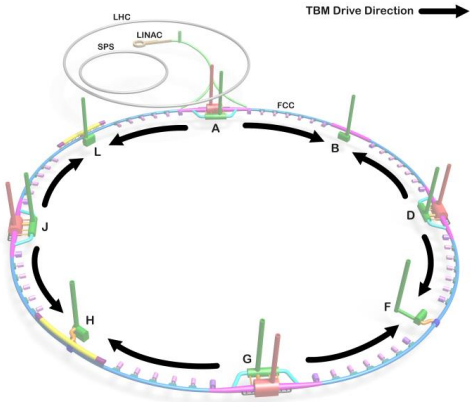
- Contract strategy for underground works is strongly influenced by TBM drivage and removal sequence.
- From a technical perspective it is considered better to drive two TBMs from each of the four experimental sites rather than a single TBM from each of the eight sites because:
  - Two shafts allow for better provision of ventilation and ability to separate material and personnel access to underground
  - The experiment shaft is directly on the axis of the beam tunnel making TBM installation easier
  - The necessary tunnel widenings can be used to assemble the TBMs underground
  - More efficient surface construction sites as the same configuration is used for two TBMs
  - Focuses construction infrastructure and spoil removal infrastructure at only four sites.
  - Allows earlier release of the technical sites for subsequent infrastructure installation activities.



A downside of this is that the single shaft in CH (PB) has no TBM drives and therefore only a small volume of spoil being removed (about 4% of the total).

Contract Strategy for Construction

The strategy for division of the work scope is based on the following factors:



- The total quantity of work is several billion CHF
- The need to maintain as far as possible a fair return to member states
- The need to minimise and simplify the interfaces between contractors
- The need to make the value of work packages large enough to attract major industry players
- The need to make the work packages of a size (value) that will attract not only the very largest of contractors from member states
- The need to maintain an option to start the construction of the Injector complex earlier than the rest of the civil works.

On this basis, the current strategy is to have five construction contracts, four for the main works and a stand-alone contract for the injection complex and transfer tunnels.

Areas of Geological Uncertainty

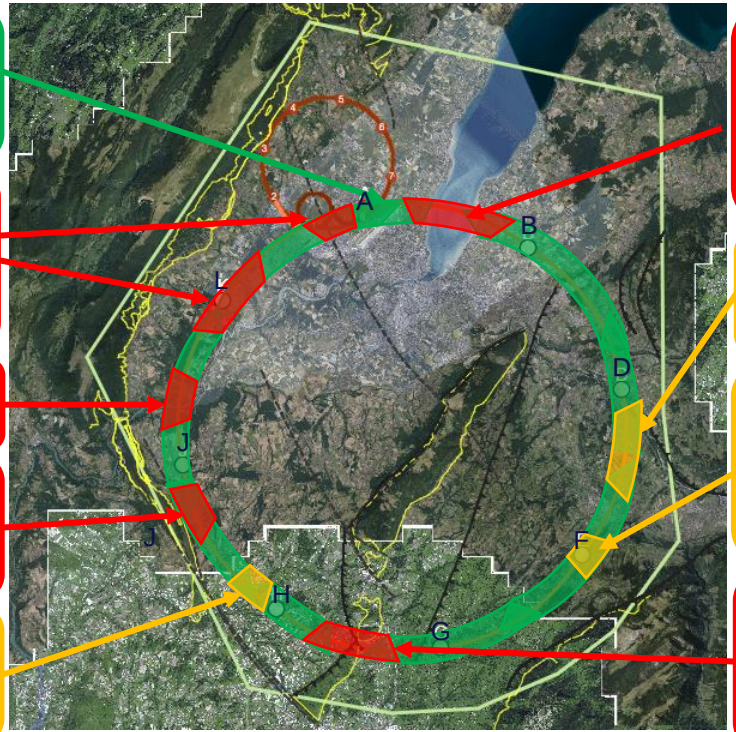
- Good knowledge of the ground (e.g. information near to CERN from LEP/LHC projects)

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

Le Rhône
- Moraine/molasse interface uncertain

Vuache
- Limestone/molasse interface not certain.
- Proximity to active fault

Les Usses
- Moraine/molasse interface uncertain.
- Low tunnel rock cover



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

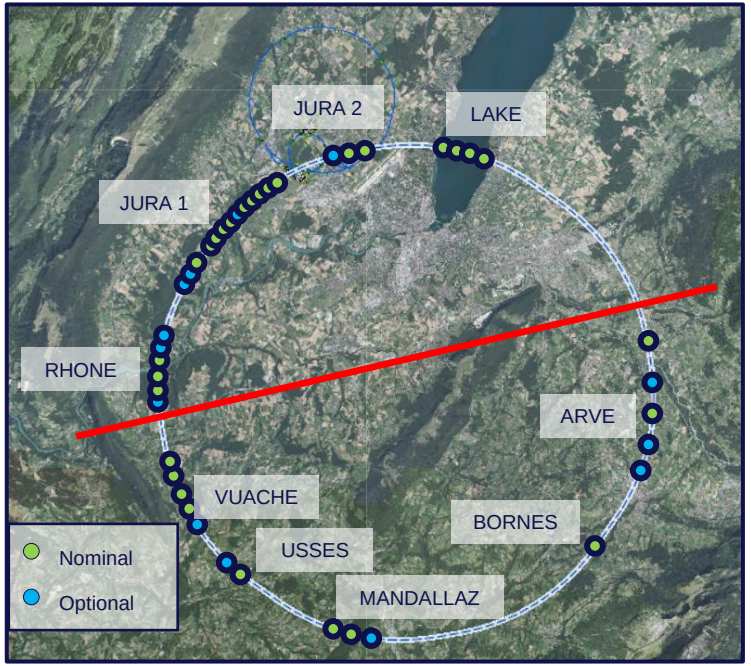
Vallée de l'Arve
- Moraine/molasse interface uncertain.
- Lack of reliable borehole information

Bornes
- Insufficient deep borehole information
- Complex faulted region
- Quality of molasse is uncertain.

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

Site Investigation Phase 1

- Original plan was to award a single contract for full scope.
- This was amended as CERN received only two offers, both close in value
- Contracts to 4 major member states (FR/CH/UK/IT) and gives CERN more flexibility to allocate works
- Engages more industrial partners ahead of larger future SI campaigns
- 4 shaft boreholes not located in target areas were postponed to the future campaign
- Geophysics scope remained unchanged



Division of SSI scope

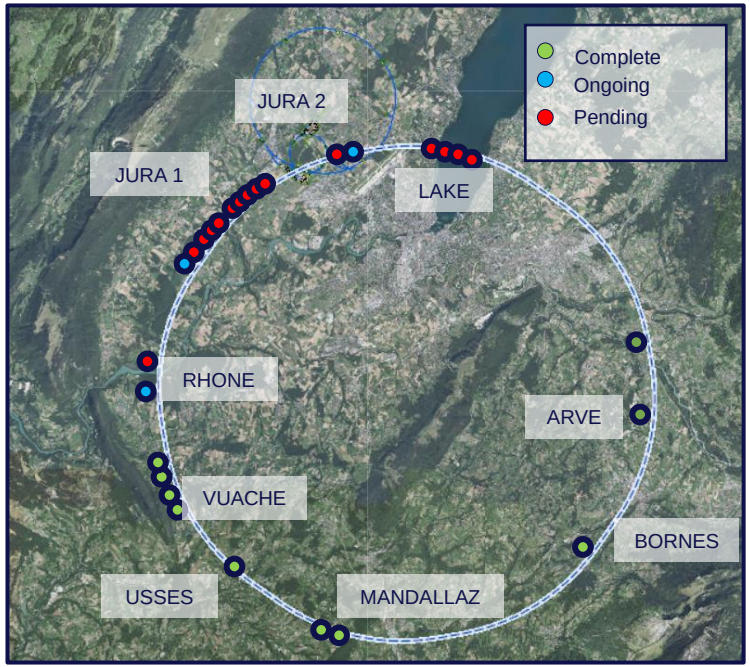
Overview of Works

South-western work package **SGS3**

- Works began in October 2024
- Geophysics acquisition complete and interpretation ongoing
- Drilling activities complete for all 10 boreholes
- Testing and report preparation ongoing

North-eastern work package **GEOTEC-IOI**

- Works began in France in April 2025
- Drilling activities ongoing on 3 boreholes
- Geophysics planned for September 2025 due to environmental constraints
- Still awaiting permits for drilling and geophysics in Switzerland



Preliminary Results

Usses Valley

- Tunnel is shallow (about 60m depth)
- Molasse encountered after 14m drilling
- Geophysics are being processed but seems the interface is fairly consistent in this region
- Positive result as assures that tunnel will be in molasse rock

Mandallaz

- Looking for extent of limestone outcrop
- 1 vertical and 1 inclined drilling
- Limestone extent seems to be less than previously thought
- Known fault was not intersected
- Karst encountered but without water

Vuache

- Looking for roof of limestone
- 4 boreholes undertaken and 5 seismic lines
- Results indicate that current horizon is well within good quality, impermeable molasse

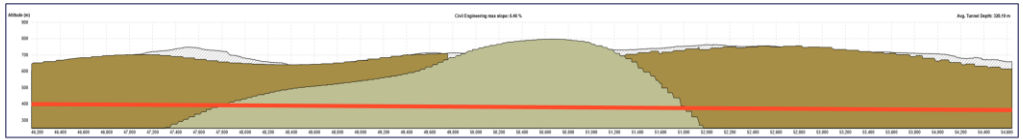
Arve (provisional)

- 2 drill sites both recently completed
- Initial results indicate shaft at PD will be predominantly in the molasse and the tunnel fully within molasse.

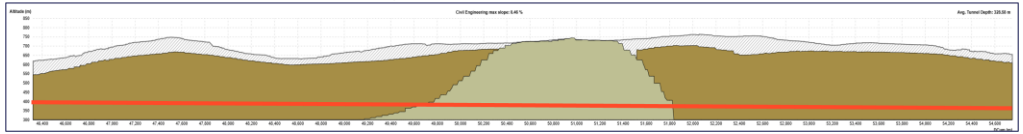
Rhone (provisional)

- First drilling has started and shows thick layer of moraine
- Results from both drill sites will be required to determine more accurate location of molasse under the Rhone river.
- Second borehole can only be done in September as it is in an environmentally sensitive area.

Preliminary Results

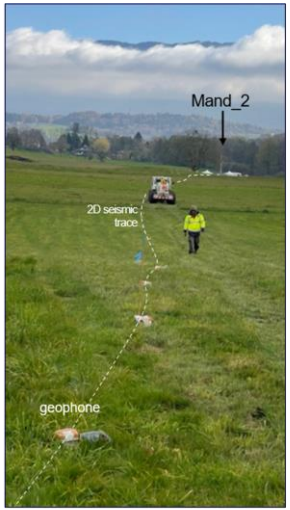


Mandallaz profile based on baseline ILF/GADZ model

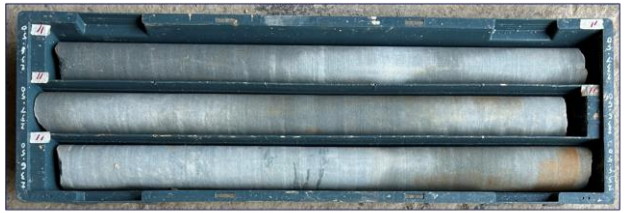


Mandallaz profile based on UNIGE v5. model

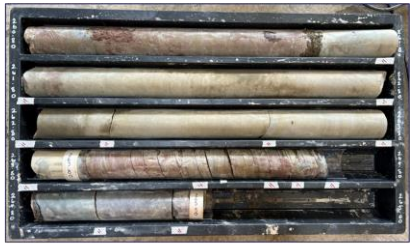
Mandallaz work sites



Mandallaz seismic works



Molasse cores from Vuache_2 site



Molasse cores from Vuache_4 site

Pre-TDR Work Scope

For underground civil engineering works to start in early 2033 there are a number of critical tasks that CERN must complete during the Pre-TDR phase ie between now and early 2028.

These tasks cover five main areas:

1. Complete the current site investigation campaign
2. Prepare for the second site investigation campaign
3. Develop the surface sites in conjunction with professional architects and engage with stakeholders to develop acceptable solutions
4. Continue to improve the maturity of the underground designs and study some specific technical topics with the aim to reduce overall cost, schedule and technical risks.
5. Advance on the design maturity for the injection complex including impact assessments for the existing structures and infrastructure.

FCC

Thank you
for your attention.