CIVIL ENGINEERING STUDIES FOR MAJOR PROJECTS AFTER LHC

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Abstract

CERN civil engineers are heavily involved in studying several major potential **collider** projects to succeed/complement the LHC. Infrastructure works typically represent one third of the cost of major physics projects, so it's critical that the construction costs are well understood from the conceptual stage. For example, CERN are studying infrastructure requirements for the Linear Collider (CLIC & ILC) and the LHeC projects. This paper presents some of the key civil engineering challenges faced in such large scale projects.

COLLIDER PROJECTS UNDER STUDY

Figure 1 shows a schematic layout for several potential future collider projects under consideration:

- CLIC (Compact Linear Collider) at collision energies of 500GeV and 3 TeV;
- ILC (International Linear Collider) at 500GeV energy;
- The Linac-Ring Solution of LHeC (A new electron beam supplied via a 60 GeV Energy Recovery Linac (ERL) colliding with LHC beam).

All the projects currently under consideration would be sited in the North-Western part of the Geneva region at the existing CERN laboratory. The proposed Interaction Regions are fully located within existing CERN land at LHC Point 2 for LHeC, close to the village of St.Genis, in France and on the CERN Prevessin Site for CLIC and ILC.

The CERN area is extremely well suited to housing such a large project. Ground conditions are very stable and well understood, thanks to the construction of several particle accelerators over the past 50 years. The civil engineering works for the most recent machine, the LHC were completed in 2005, so excellent geological records exist and have been utilised for these studies to minimise the costs and risk to the project. Any new underground structures will be constructed in the stable Molasse rock at a depth of 100-150m in an area with little seismic activity.

CERN and the Geneva region have all the necessary infrastructure at their disposal to accommodate such a project. Due to the fact that Geneva is the home of many international organizations excellent transport and communication networks already exist. Geneva Airport is only 5km from the CERN site, offering direct international links and a newly constructed tramway links directly to the main Geneva Railway Station.

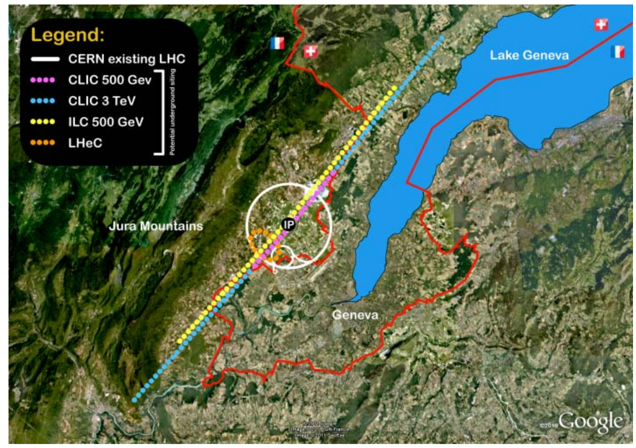

Figure 1: Schematic layout of existing and potential future projects (underground sitting only).

GEOLOGY

New tunnels for these projects would be housed within the Geneva Basin, a sub-basin of the large North Alpine Foreland (or Molasse) Basin. This is a large basin which extends along the entire Alpine Front from South-Eastern France to Bavaria, and is infilled by Molasse deposits of Oligocene and Miocene age. The basin is underlain by crystalline basement rocks and formations of Triassic, Jurassic and Cretaceous age. The Molasse, comprising an alternating sequence of marls and sandstones (and formations of intermediate compositions) is overlain by Quaternary glacial moraines related to the Wurmien and Rissien glaciations. A simplified geological long profile for the CLIC machine is shown in Figure 2, indicating the average depth of tunnels would be approximately 100 – 150m below existing ground level (drawing produced by AMBERG Engineering).

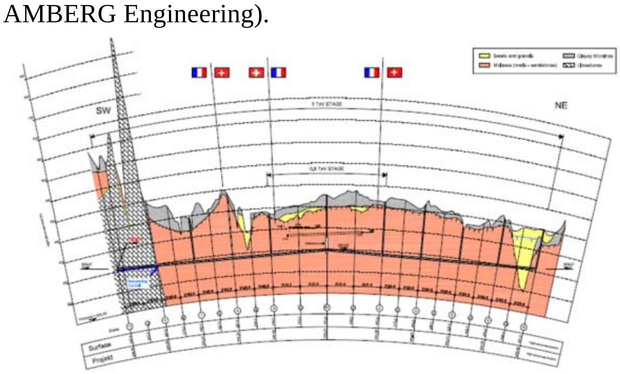

Figure 2: Simplified Long Profile for CLIC [1].

CONSTRUCTION METHODS

Figure 3 shows a Tunnel Boring Machine (TBM). It is envisaged that this type of excavation machine will be utilised for any tunnel excavation greater than approximately 2km in length. In the Molasse rock, a shielded TBM will be utilised, with a single pass pre-cast segmental lining, followed by injection grouting behind the lining. For planning and costing exercises, an average TBM advancement of 25m per day, or 150m per week is predicted.

Figure 3: TBM used for CERN Neutrino tunnel.

Second phase excavation will be executed using a “roadheader” type machine, for example, for the CLIC ‘turnarounds’.

Any new shafts that have to pass through substantial layers of water bearing moraines (for example at CMS) will have to utilize the ground freezing technique. This involves freezing the ground with a primary cooling circuit using ammonia and a secondary circuit using brine at -23°C, circulating in vertical tubes in pre-drilled holes at 1.5m intervals. This frozen wall allows excavation of the shafts in dry ground conditions and also acts as a retaining wall.

TUNNEL CROSS SECTION

The internal diameter for the Main LINAC for CLIC has been fixed at 5.6m. A 10cm margin has been added to the internal radius of the tunnel to allow for construction tolerances. This diameter was optimised via inserting all known machine components/services into a 3D model while maintaining a space for transport vehicles and safe passage of personnel. This diameter is within the common range of TBM’s utilised for metro transportation tunnels, which means machinery and spare parts are more easily found on the market.

A driving factor for the tunnel diameter is the overhead ventilation ducting. Unlike the LHC tunnel, which uses the longitudinal ventilation concept, a semi-transversal ventilation scheme has been adopted.

In order to minimise vibration from the cooling pipes embedded in the tunnel floor, the in-situ concrete will be placed in two halves. That is to say, a vertical separation joint of compressible filler will be placed in-between the area of the slab housing the pipes, and the area supporting the accelerator. Figure 4 shows a typical cross section for the CLIC tunnel.

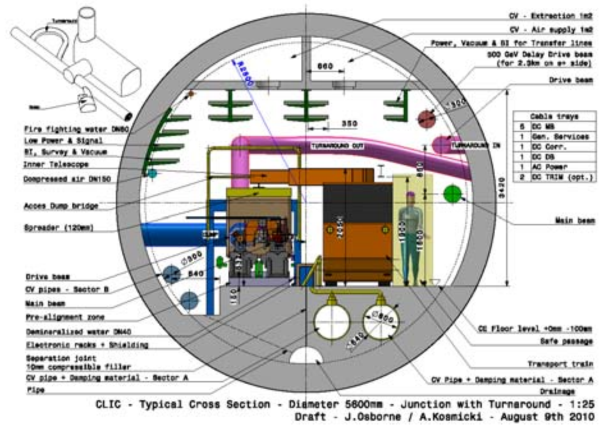

Figure 4: Typical tunnel cross section for CLIC.

INTERACTION REGION DESIGN

A detailed design study is underway with assistance from a UK based company, ARUP, for the Interaction region of CLIC. This desk based assessment of existing geological data and known geotechnical rock characteristics at CERN, will be utilized to assess the in situ stress conditions of the underground cavern complex.

A 3D CAD model of the current layout of the CLIC detector halls has been developed. This will provide input into an elastic boundary element model in order to study the potential for over-stressed ground which can lead to time-dependent and inelastic behaviour.

The design is currently being developed, bearing in mind that at a future date, a similar study could be performed for other sites such as the Fermilab area in Chicago or Japan for the ILC Interaction Region. Figure 5 shows some preliminary modelling for the CLIC Interaction Region.

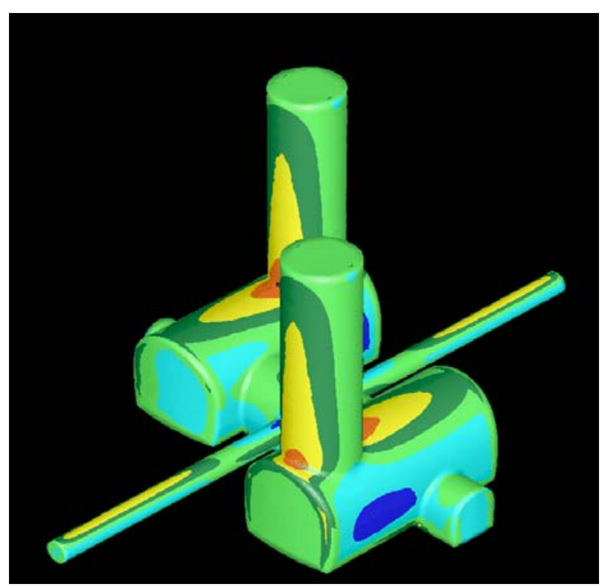

Figure 5: Cavern Stress State for CLIC IR [2].

INFRASTRUCTURE COSTS

Apart from civil engineering, many other infrastructure challenges are being studied for these types of projects, such as, cooling & ventilation, electrical supply, transport & installation etc. Typical costs for LHC infrastructure are represented in the pie-chart shown in Figure 6. For major new projects like those presented on this poster, we can expect a similar distribution of costs for the key infrastructure items.

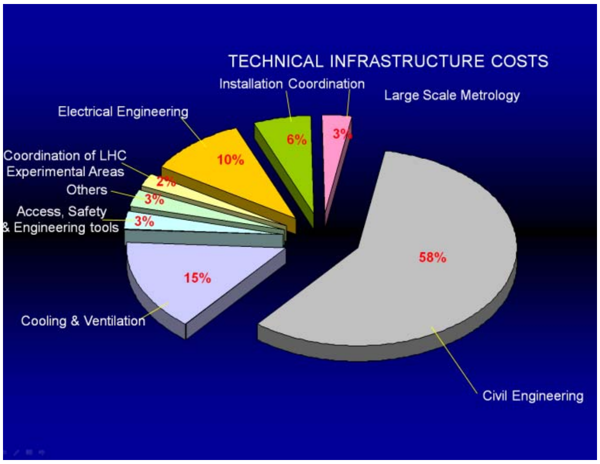

Figure 6: LHC cost distribution for Infrastructure.

CONCLUSION

CERN civil engineers will continue in the future to be heavily involved in the design developments of collider projects such as those mentioned in this paper.

REFERENCES

[1] CLIC Long Profile drawing produced by Amberg Engineering.
[2] Interaction Region stress modelling is being performed by ARUP Consulting (London Office).