CIVIL ENGINEERING FEASIBILITY STUDIES FOR FUTURE RING COLLIDERS AT CERN

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Abstract

CERN civil engineers are studying the feasibility of several potential ring colliders to complement the LHC: an 80km circular tunnel to house the TLEP and VHE-LHC, and the ring-ring and linac-ring options for the LHeC. The feasibility of these projects is largely dependent on civil design and geotechnical and environmental risks. As civil infrastructure works typically represent one third of the cost of major physics projects, it is critical that the construction costs are well understood from the conceptual stage. This proceeding presents the first results of the feasibility studies for the 80km tunnel and the linac-ring LHeC.

PROJECT SPECIFICATIONS

Two new circular tunnels are currently considered to house the following projects at CERN: the **TLEP** (Triple LEP), **VHE-LHC** (Very High Energy LHC) and the **LHeC** (Large Hadron Electron Collider).

Civil engineering feasibility studies are carried out based on the following assumptions: the TLEP and VHE-LHC will be housed in the same tunnel. This tunnel should have a minimum length of 80km and be connected to either the LHC or the SPS at one point. Shafts are located approximately every 10km. Shaft depths should be minimized as much as possible. Two experimental caverns with connecting shafts are considered.

Regarding the LHeC, it is assumed both the ring-ring and linac-ring options would require about 10km of tunnelling, located as much as possible on CERN land and in the Molasse rock. The ring-ring option is housed in the LHC tunnel with new bypass tunnels around LHC points 1 and 5 plus three new shafts. A racetrack shaped linac, injecting into LHC at point 2, plus two new shafts are assumed for the linac-ring option (see Fig. 1).

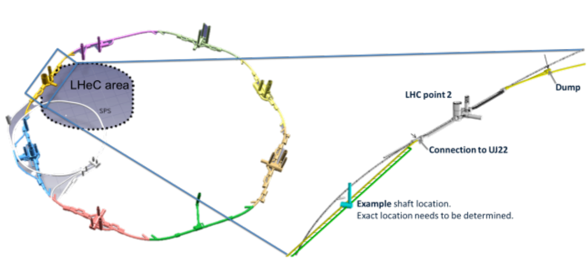

Figure 1: Schematic layout of the linac-ring LHeC project.

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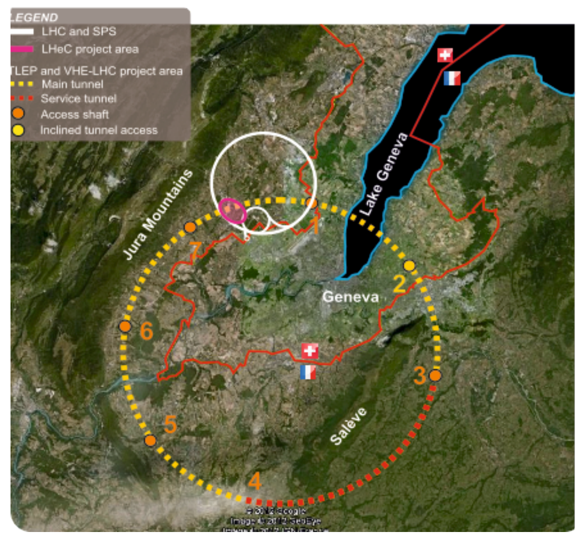

Figure 2: Map of existing CERN tunnels, the preferred option for the 80km tunnel and the linac-ring LHeC project area. The ring-ring LHeC is not highlighted.

For all these projects it is important to ensure a design that minimizes the impact on the environment. Fig. 2 shows potential locations of the projects.

FEASIBILITY STUDIES

The civil engineering feasibility studies are composed of a multitude of individual studies, e.g. civil design, geotechnical, excavation, environmental impacts, and costs, which together determine the projects' viability. The focus here is on the LHeC linac-ring option, and three different locations for TLEP/VHE-LHC, shown in Fig. 3.

Geology

Geology is a key in determining the feasibility of an excavation project. In the project areas three main geology types are encountered: Limestones (TLEP/VHE-LHC), Molasse rock (LHeC and TLEP/VHE-LHC) and Moraines (LHeC and TLEP/VHE-LHC), shown in Fig. 3.

Jurassic and Cretaceous Limestones are found in the Jura and Salève mountains. Fractures and Karsts (active and passive) are common features. Shaped by Cenozoic thrusting and folding, minor Tertiary evaporates are expected to be present in the deeper parts of the Jura mountain.

The Geneva area is located in the Geneva basin (between the Jura and Salève mountain ranges), which is a sub-basin of the North Alpine Foreland (or Molasse) Basin. This is a large basin, which extends along the

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Alpine Front from South-Eastern France to Bavaria, and is infilled by Oligocene and Miocene Molasse deposits, comprising of alternating sequences of marls, sandstones and formations of intermediate composition. The Molasse is characterized as soft and relative impermeable rock. Molasse remnants are also found in the Jura mountain valleys.

Overlying the Molasse rock are Quaternary glacial deposits, called Moraines. These formations comprise clays, silts, sands and gravels. The sands and gravels usually contain water used for drinking water supply.

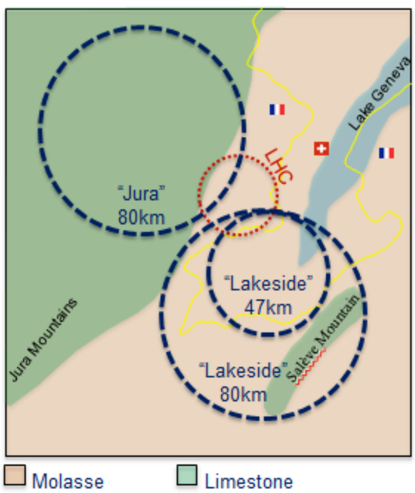

Figure 3: Simplified geological map of the Geneva region.

Geotechnical Feasibility

Together with the UK based specialized firm ARUP geotechnical issues related to the TLEP/VHE-LHC underground constructions in both the Jura and Lakeside locations were studied. Geotechnical concerns related to Limestones are only applicable for the TLEP/VHE-LHC project, risks related to Molasse and Moraines are valid for both the TLEP/VHE-LHC and the LHeC project.

Limestone risks are mainly related to risk of water inflows during and after construction. Large inflows are dangerous, expensive and difficult to remedy. They can create substantial delays to the program and have long-term risks and environmental impacts. Inflows may occur when excavating through active karst zones or sediment filled vaults. Most severe problems are expected to occur in the Jura limestone (80km Jura option) where karstically active fault zones and high water pressures are known to exist. However, it is difficult to predict the exact location of these features and the effects of karsts should be studied extensively (see Fig. 4).

Besides inflow during excavation, the risk of tunnel collapse exists due to water pressure build up behind the tunnel wall. Risks associated with water inflow are increased by silty and clayey suspended solids, which cause difficulties for water removal and can pose a risk of increased inflow over time due to linking with previously unconnected aquifer systems.

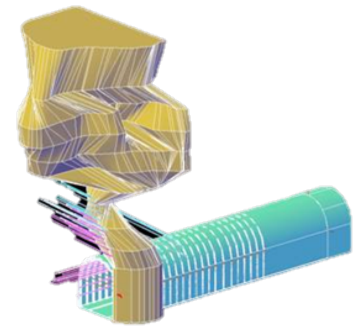

Figure 4: Model of karsts effects on tunnels.

Triassic marls containing the mineral anhydrite pose another risk mainly for the TLEP/VHE-LHC Jura option. The creation of underground space and the potential introduction of water may cause the anhydrite to swell, causing heaving of the tunnel floor and thereby affecting the stability of the underground construction. More detailed studies will have to be carried out to determine the adequate stabilization actions.

Molasse risks, related to tunnelling in Molasse, are well understood due to experiences gained from LEP and LHC excavations. The Molasse is a relatively soft and stable rock. However, some geotechnical challenges can be expected.

The Molasses deposits are very heterogeneous, containing weak marl layers between stronger calcareous strata. When disturbing the ground conditions, ground stresses will redistribute, and in the process this may cause the weaker zones to break apart. As the 80km tunnel will be located at a greater depth than the LHC, these effects may become more significant due to the higher overburden pressures. To prevent unwanted ground convergence and plastic deformation during tunnelling an adequate support and lining is needed.

Moraine risks are encountered during shaft excavation and sinking. Major construction issues are related to the water bearing units, which are not always clearly defined. Water flow will have to be controlled by using either diaphragm walling or groundfreezing. The groundfreezing technique 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. This frozen wall allows excavation of the shafts in dry ground conditions and also acts as a retaining wall.

Another important geotechnical feasibility issue is related to the fact that the 80km lakeside option passes under Lake Geneva, where the geological conditions are not yet well understood. Detailed site investigations are therefore needed to determine the exact geology and the interface between the Moraines and the Molasse.

Tunnel Excavation Methods

It is assumed that for the tunnelling sections greater than 2km through Molasse rock a tunnel boring machine (TBM) will be used, as was the case for LEP and LHC.

An open-face shielded TBM will be operated, with a single pass pre-cast segmental lining, followed by injection grouting behind the lining. An average advance rate of 25m per day, or 150m per week is predicted.

Tunnelling through limestone can either be done using Drill&Blast or tunnel-boring machines (TBM). The main differentiators are advance rates and costs. In general, the TBM is faster, but in hard rock it can be more expensive. For long tunnelling sections a TBM is therefore considered most cost-beneficial. A cost-benefit study will have to be conducted to determine the most advanteous method. In locations with a risk of karsts, Drill&Blast is preferred as this allows free access to the face for grouting and dewatering.

Environmental Feasibility

A major feasibility issue for the potential projects is the acceptance of the environmental impact assessment (EIA), which will have to be approved by the respective authorities. The environment is therefore considered an important part of the siting and feasibility studies (design, construction methods, etc). While the EIA is a long and complex process, some major issues have already been identified.

Aquifers in the Moraines in the Geneva region are used for public water supply and are strictly protected by law. The karsts in the Jura Limestones play an important part in recharging these aquifers. Risks such as reduction of the water supply due to pumping from the tunnels and pollution of the aquifers due to civil engineering works should be avoided.

Natural parks are common in the Geneva area, such as the Jura Mountains regional park, the Salève forest and the banks of rivers (Rhône, Arve, Allondon etc.). Like the aquifers, most of the natural parks are protected by law. The impact on the parks extends beyond the actual excavation works; noise, air pollution, light, waste and other pollution hazards will have to studied extensively and mitigation and monitoring plans will have to be set up.

Landscape will be affected by the civil works, as spoil will have to be disposed of and items such as shafts, surface buildings, roads and power lines will change the landscape.

Hydrocarbons and associated methane are present in the Molasse. During the excavation of the LHC 250 tonnes of hydrocarbon contaminated rock was excavated, which had to be safely disposed off. Hydrocarbons are also expected to be present in the Limestones.

Cost Feasibility

Together with the specialized firm Amberg Engineering AG, CERN civil engineers are studying the cost feasibility of potential future projects as presented here. From experience (LEP, LHC, LINAC 4) we can expect the following civil engineering costs division: 62% for underground construction, 26% for surface works and 12% for outsourced consultancies.

Apart from civil engineering, many other infrastructure challenges will have to be studied during the next project phases. These include, among others, cooling & ventilation, electrical supply and transport & installation. Typical costs for LHC infrastructure are represented in Fig. 5. For major new projects like the TLEP/VHE-LHC and the LHeC, we can expect a similar distribution of costs for the key infrastructure items.

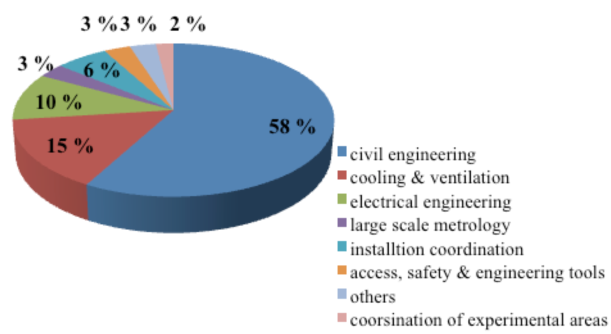

Figure 5: LHC infrastructure cost distribution.

CONCLUSION

CERN civil engineers have identified some key feasibility issues for the potential ring colliders at CERN. They will continue to study these concerns in depth and be heavily involved in the design development.

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