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Civil Engineering for the SHiP Facility

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Abstract

The enlarged scope of the recently proposed experiment to search for Heavy Neutral Leptons, SPSC-EOI-010, is a general purpose fixed target facility which in the initial phase is aimed at a general Search for Hidden Particles (SHiP) as well as tau neutrino physics. This report represents an annex to the SHiP Technical Proposal summarizing the civil engineering considerations for SHiP.

Modifications

Revisions	Date	Pages	Description
0.1	18/03/2015	24	Creation of document
0.2	19/03/2015	24	Handling of concrete from TDC2 and additional cost included within the estimation
0.3	20/03/2015	24	Text corrections

Contents

6 Civil engineering for the SHiP facility

6.1 Overview

Civil Engineering costs for projects such as SHiP typically represent approximately one third of the overall budget. For this reason, particular emphasis has been placed on Civil Engineering (CE) studies, to ensure a cost efficient conceptual design. This chapter provides an overview of the designs adopted for the civil engineering.

The CE studies were based on the assumption that the SHIP facility will be sited on the CERN Prevessin laboratory in France. A new machine extraction tunnel will be required in the North Area, leading to a new Target and Experimental facility. All civil engineering works for the project are fully located within existing CERN land on the Prevessin campus.

The area foreseen for the development of the new SHiP facilities is encircled in Figure 1.

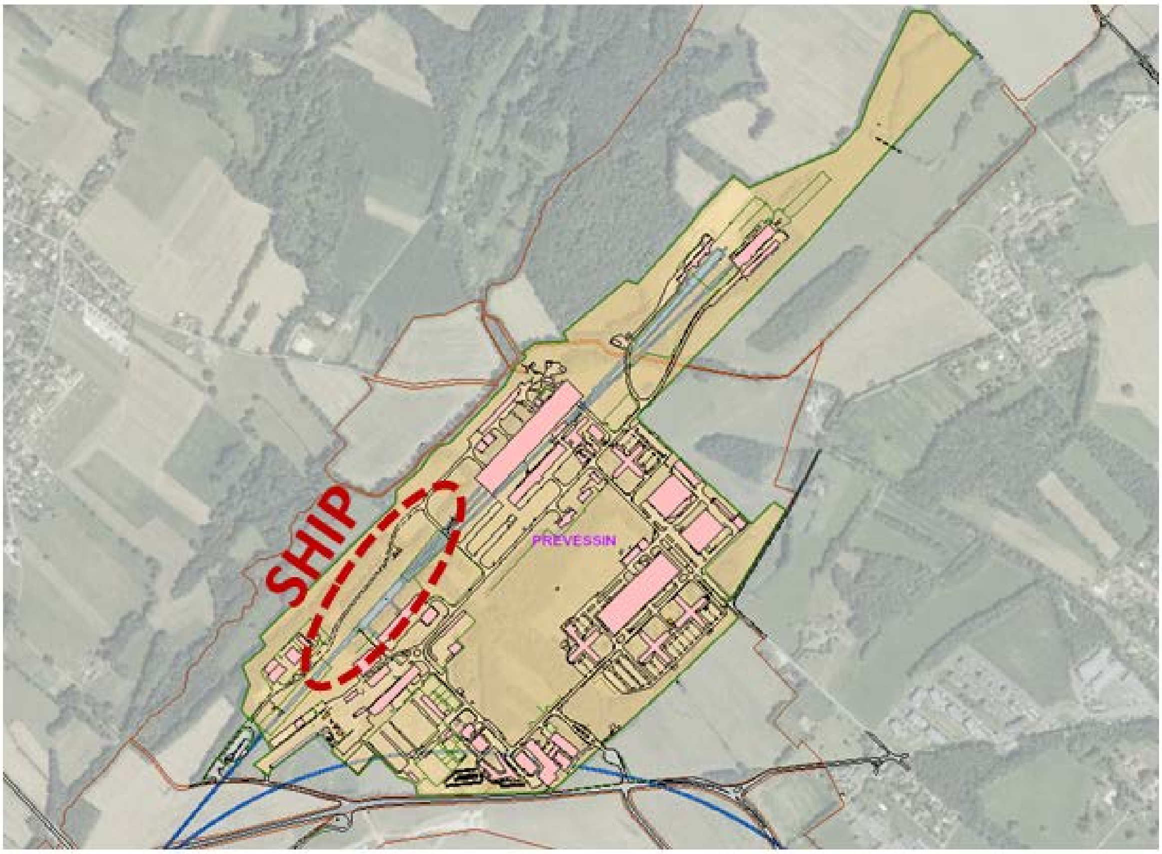

Figure 1: SHiP area on the French CERN Site in Prévessin

A comparison between the “current situation” and after with the “new SHiP facilities required” is shown in Figure 2

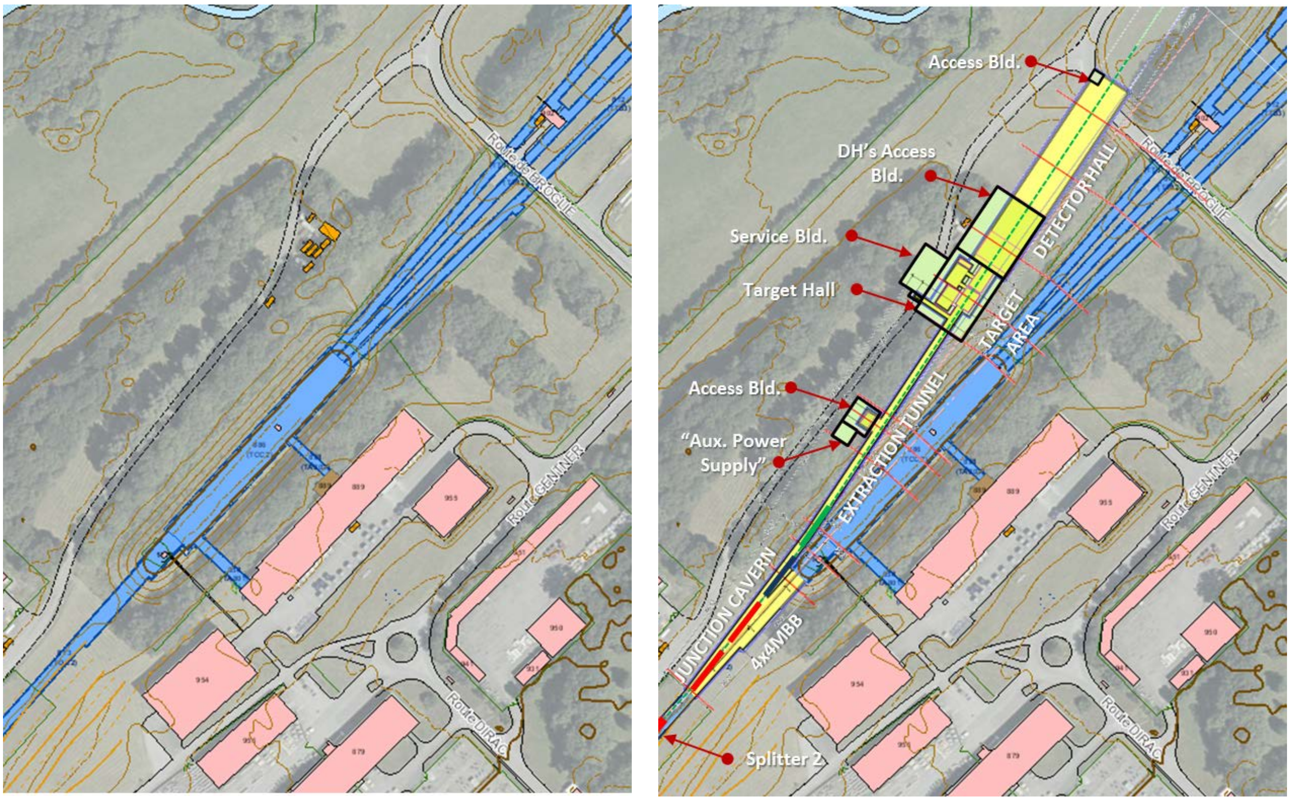

Figure 2: Existing CERN facilities and SHiP requirements

The key features of this layout are:

- Demolition of the existing TDC2 to allow new 86m long Junction Cavern replacing
- 166m long machine Extraction Tunnel (4m wide by 4m high similar to TDC2)
- 15m long by 15m wide Access building including a shaft to reach the Extraction Tunnel line
- 40m long by 30m wide Target Hall and several underground areas
- 25m long by 15m wide Service building directly connected on one side to the Target Hall
- 140m long Technical Gallery (2.5m wide by 2.5m high similar to GT801)
- 120m long by 20m wide Detector Hall
- 40m long by 30m wide Access building on top of the Detector Hall

In order to fulfil several aspects such as the minimization of the excavation volume, "improve" stability of existing tunnels, comply with the RP safe distance and respect the water table levels, all underground works are to be excavated using the "diaphragm wall" method.

The civil engineering studies presented in this chapter have been performed by the GS-SE Group with various technical experts within the SHiP team. External specialist firms have also contributed in some areas of these studies.

6.2 Civil Engineering Description

This section describes the civil engineering envisaged both on surface and underground for the SHiP Project.

6.2.1 Location

The proposed siting for the SHiP Project is fully located within existing CERN land on the Prevessin campus. The on-surface alignment of the complex consists of green areas and woodland.

This location is extremely well suited to housing the SHiP project, with the very stable and well understood ground conditions. Detailed geological records exist and have been utilised for this study to minimise the costs and risk to the project. The underground works will be constructed in the stable Moraine glacial deposits at a depth of approximately 10 m in an area with little seismic activity.

The governments of France and Switzerland have long standing agreements concerning the support of particle accelerators in the CERN region, which make it very likely that the necessary planning permissions could be granted in a relatively short timeframe.

6.2.2 Land Features

The proposed location for the project is situated within the Swiss midlands embedded between the high mountain chains of the Alps and the lower mountain chain of the Jura. CERN is situated at the feet of the Jura mountain chain in a plain slightly inclined towards the lake of Geneva. The surface terrain was shaped by the Rhone glacier which once extended from the Alps to the valley of the Rhone. The water of the area flows to the Mediterranean Sea. The absolute altitude of the surface ranges from 430 to 500 m with respect to sea level.

6.2.3 Geology

The proposed path of SHiP is situated 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 clastic “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 Quatemary glacial moraines related to the Wurmien and Rissien glaciations.

Figure 3 shows a typical geological borehole log for the Moraines in the SHiP area.

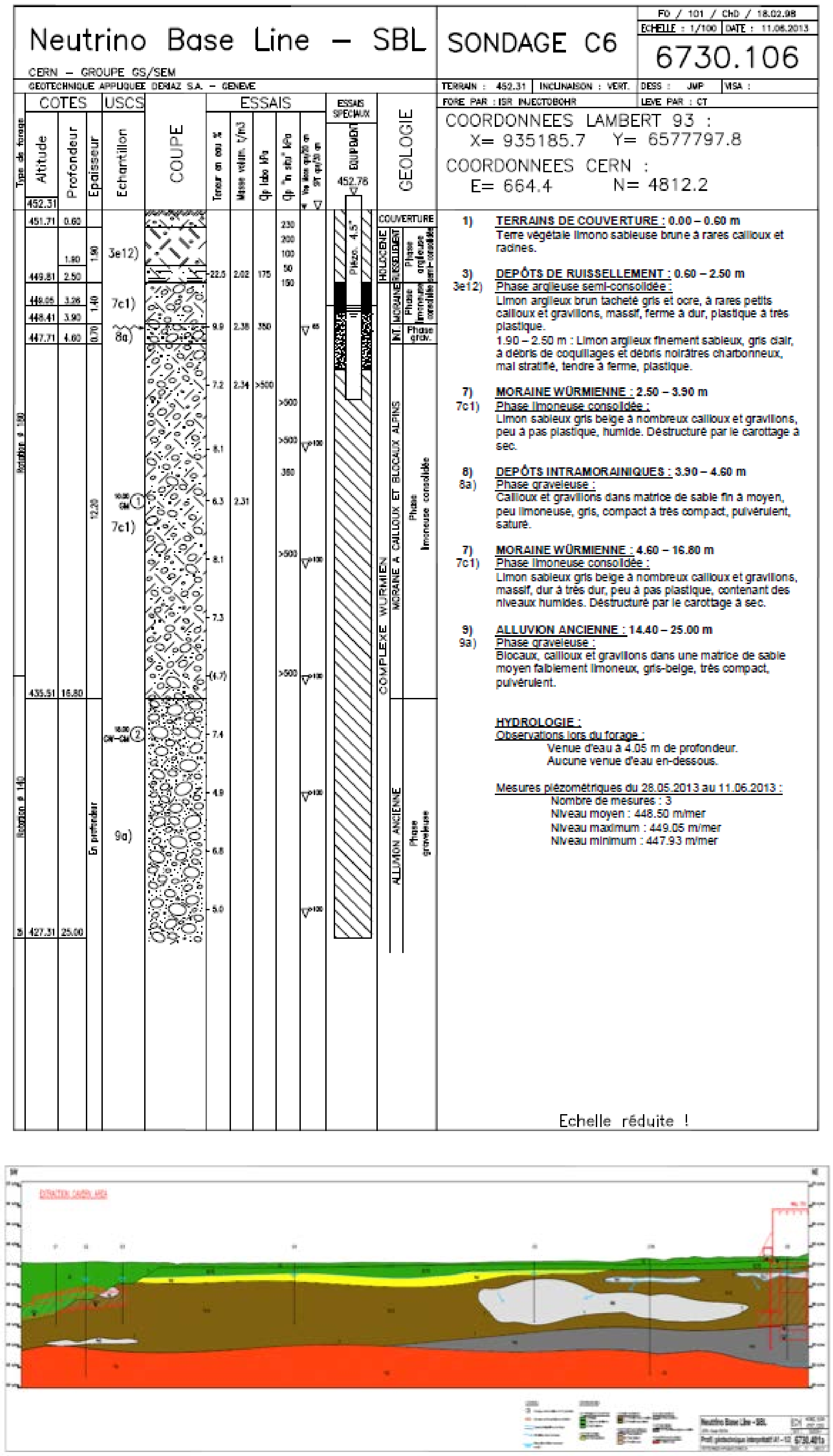

Figure 3: Typical geological borehole log and long profile for the area.

6.2.4 Site Development

As the SHiP Project is located on the CERN site at Prevessin, it is assumed that the existing facilities such as office space, restaurant, main access, road network etc are sufficient and have not been costed. However, some additional site development will need to be included in the cost estimate:

- New access road and car park
- Drainage networks
- Landscaping and planting
- Spoil dumps

All temporary facilities needed for the civil engineering works have to be included in the cost estimate, but nothing for any temporary areas/buildings needed for machine or detector assembly/installation.

6.2.5 Construction Methods

It is envisaged that all underground works will be executed using “diaphragm wall” rather than “open-cut” or tunnelling methods. The TDC2 tunnel itself was excavated in 1972 using the “cut and cover” technique.

Figure 4 shows the start of the tunnelling for the TT20 line going down towards the SPS.

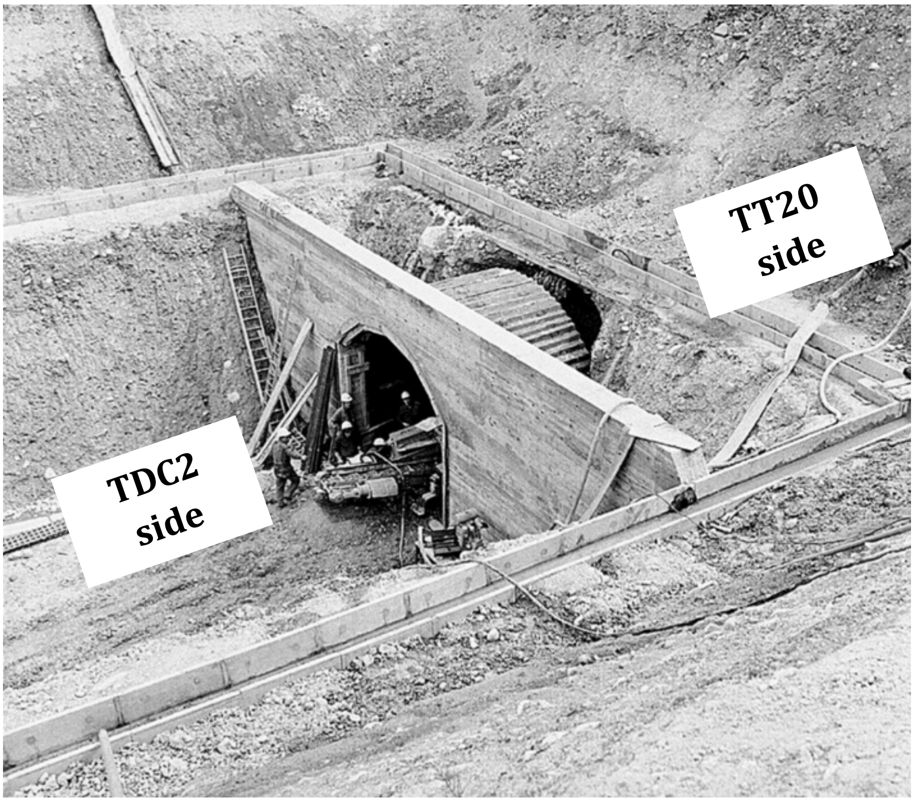

Figure 4: Photo from May1972 showing the start of tunnelling for TT20 line going down to SPS.

The new civil engineering works will be downstream of the TT20/TDC2 area.

A plan view of the new underground and surface areas required for the SHiP experiment as well as the indication of the main cross sections along the new beam-line is shown in Figure 5.

Detailed cross sections (from Figure 6 to Figure 17) provide information concerning the new facilities dimensions, the typical excavation method foreseen and the ground volume to be handled.

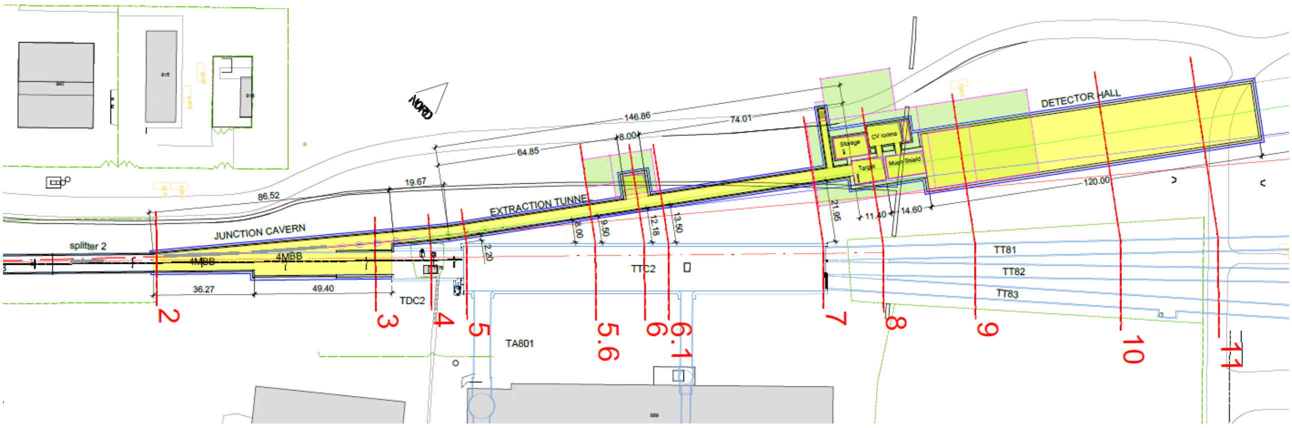

Figure 5: Top view of the new SHiP underground and surface areas with the main cross sections along the beam-line

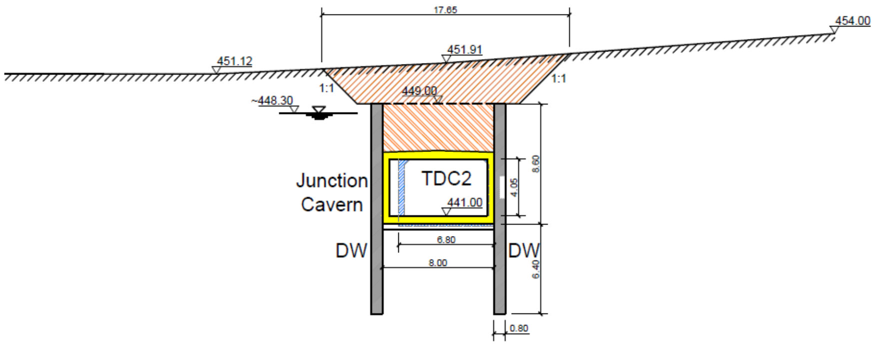

Figure 6: Cross section 2

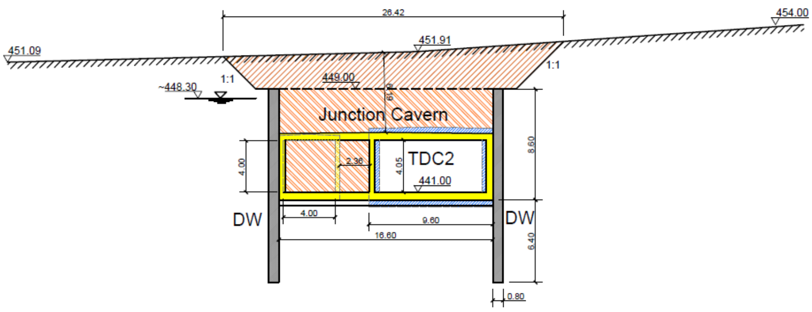

Figure 7: Cross section 3

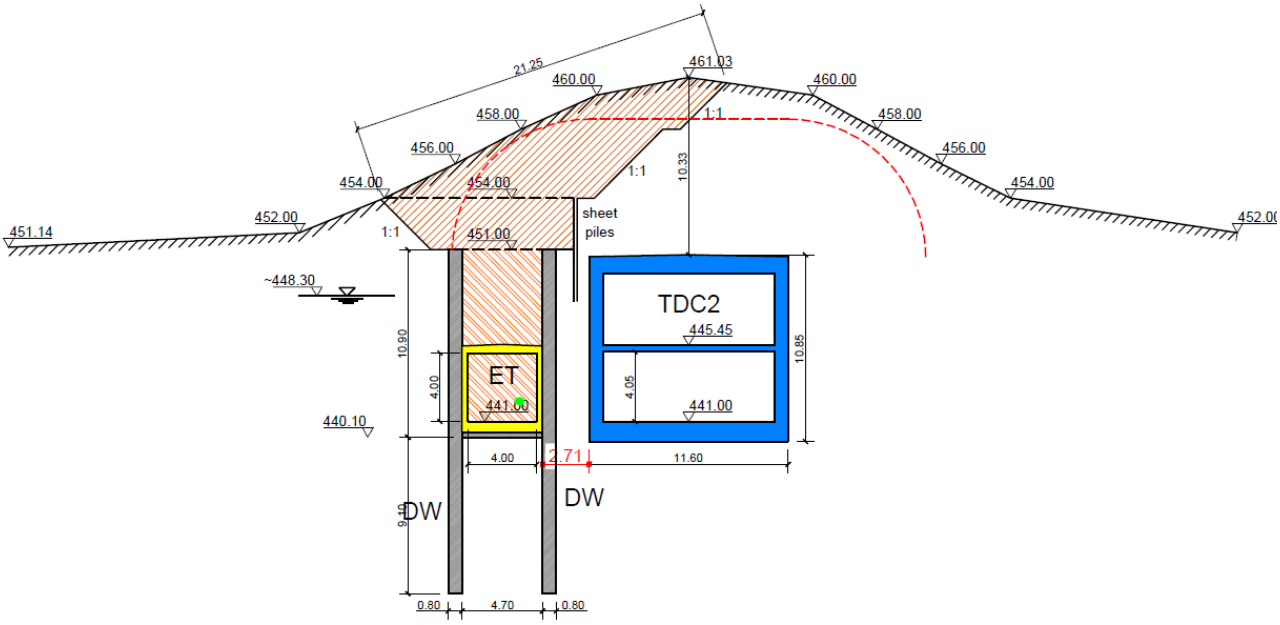

Figure 8: Cross section 4

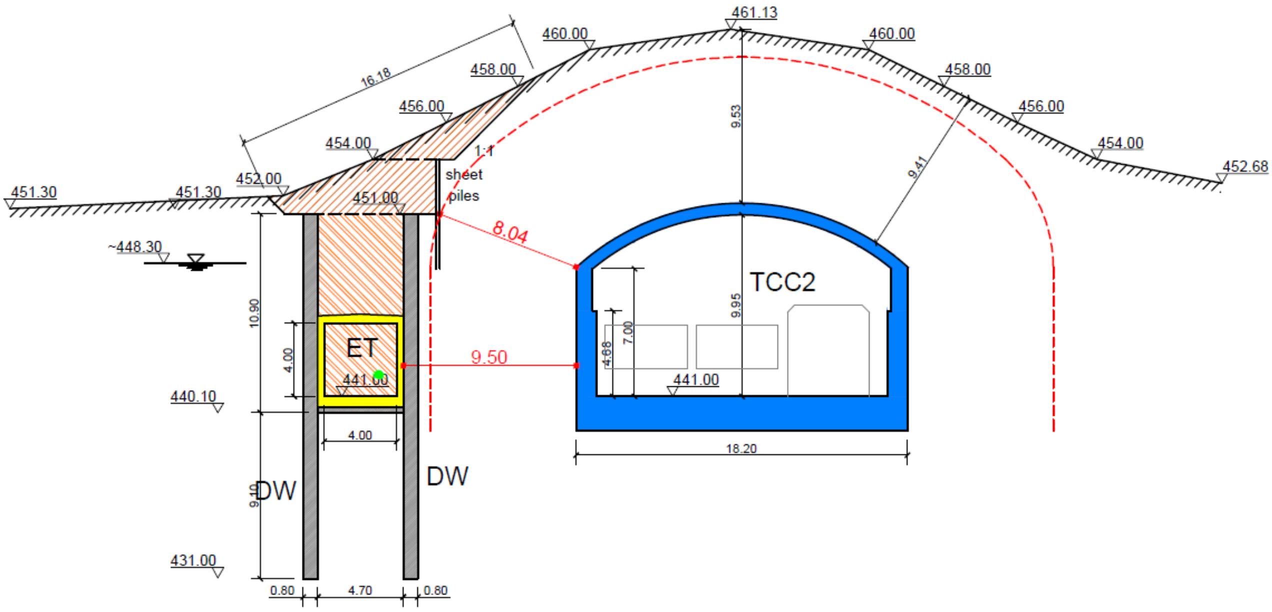

Figure 9: Cross section 5.6

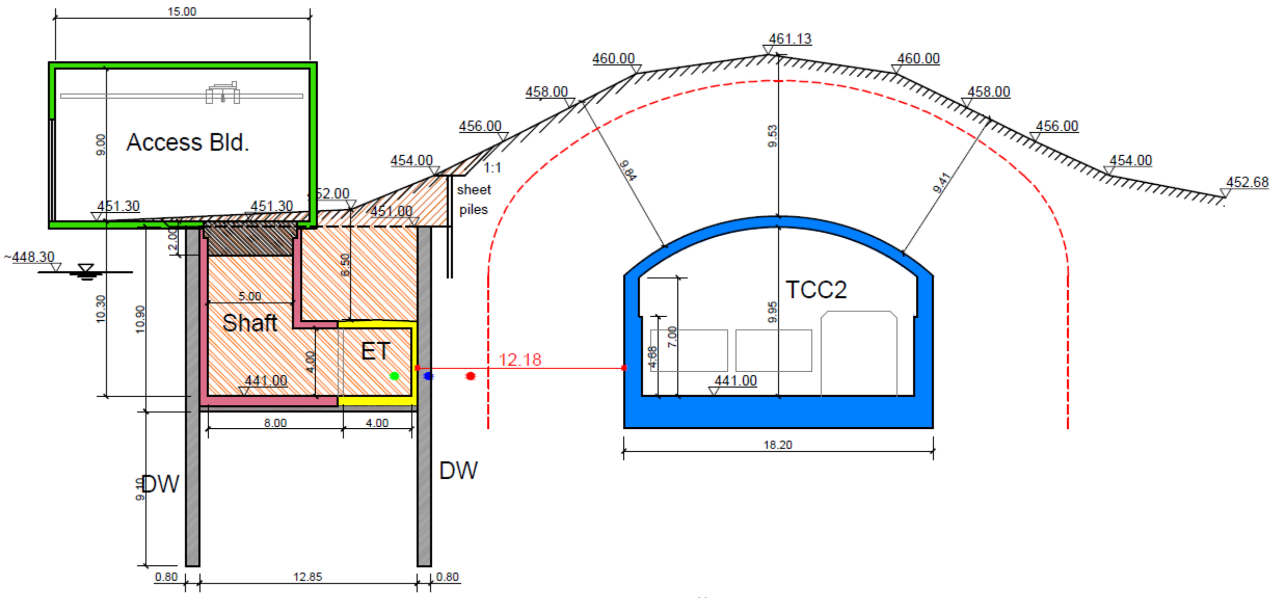

Figure 10: Cross section 6

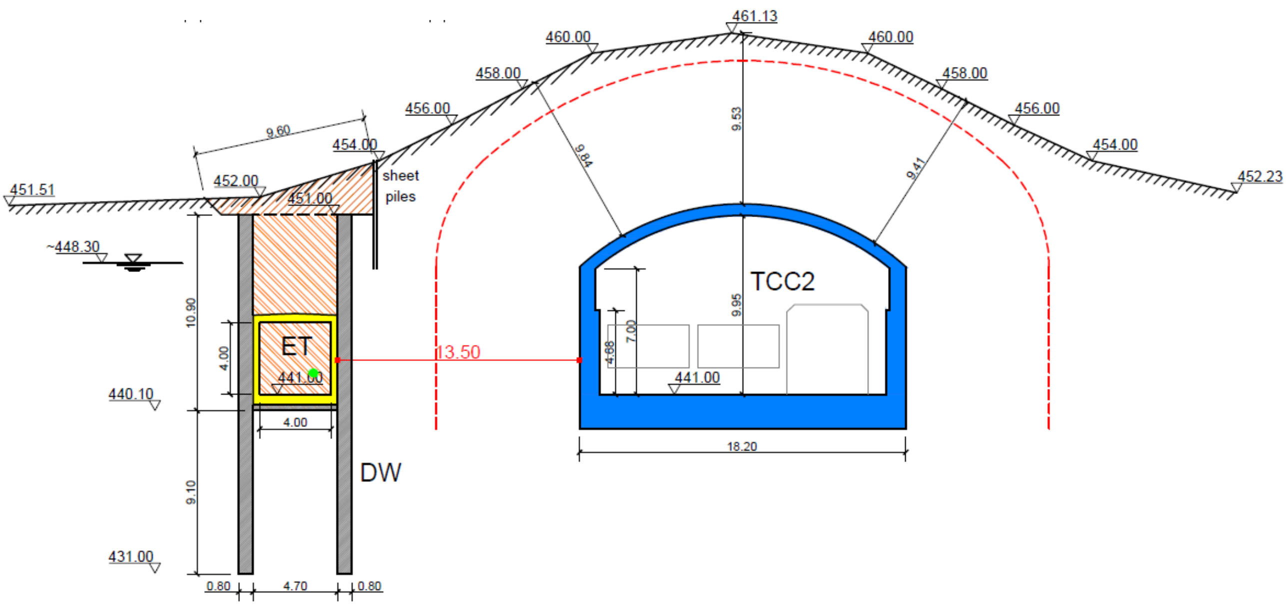

Figure 11: Cross section 6.1. Diaphragm wall are 20m depth.

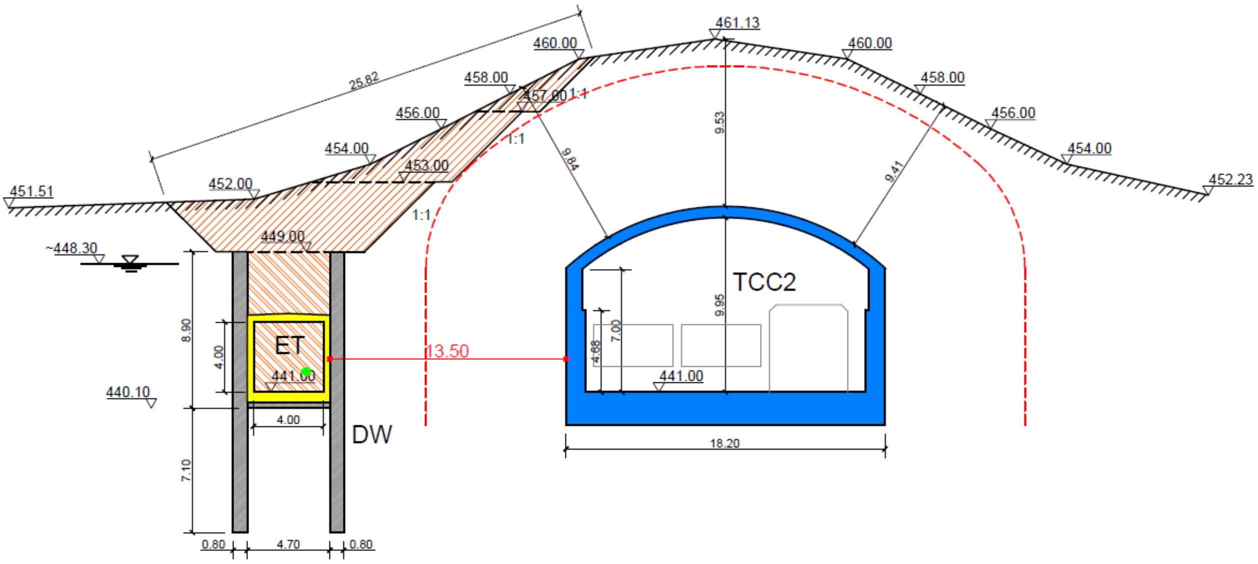

Figure 12: Cross section 6.1. Diaphragm walls are 16m depth.

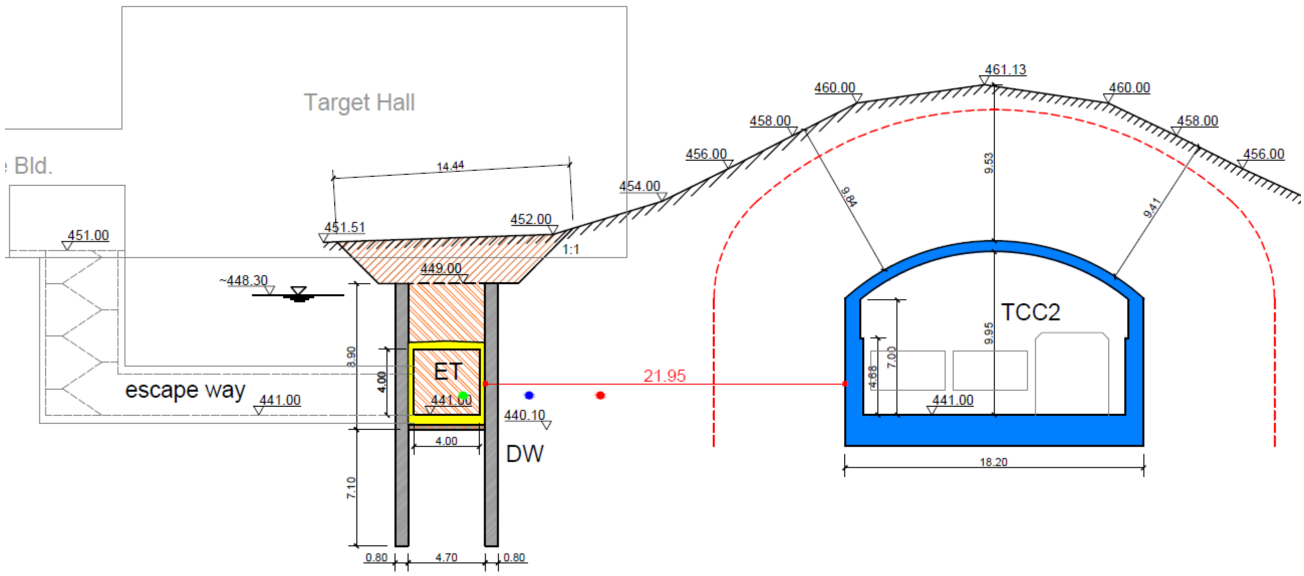

Figure 13: Cross section 7

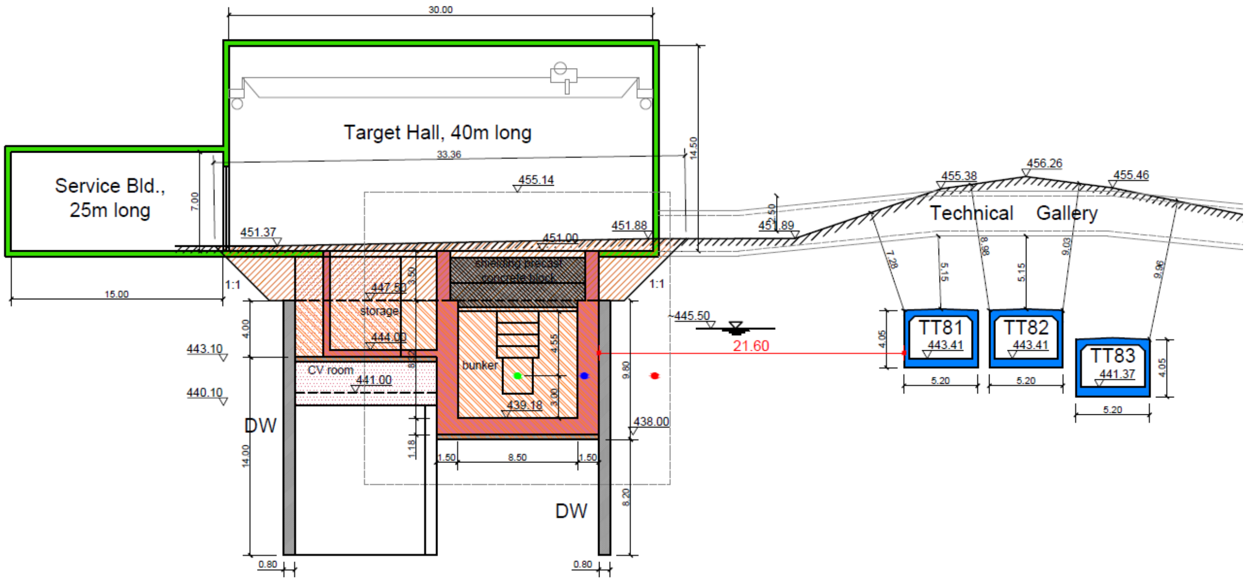

Figure 14: Cross section 8

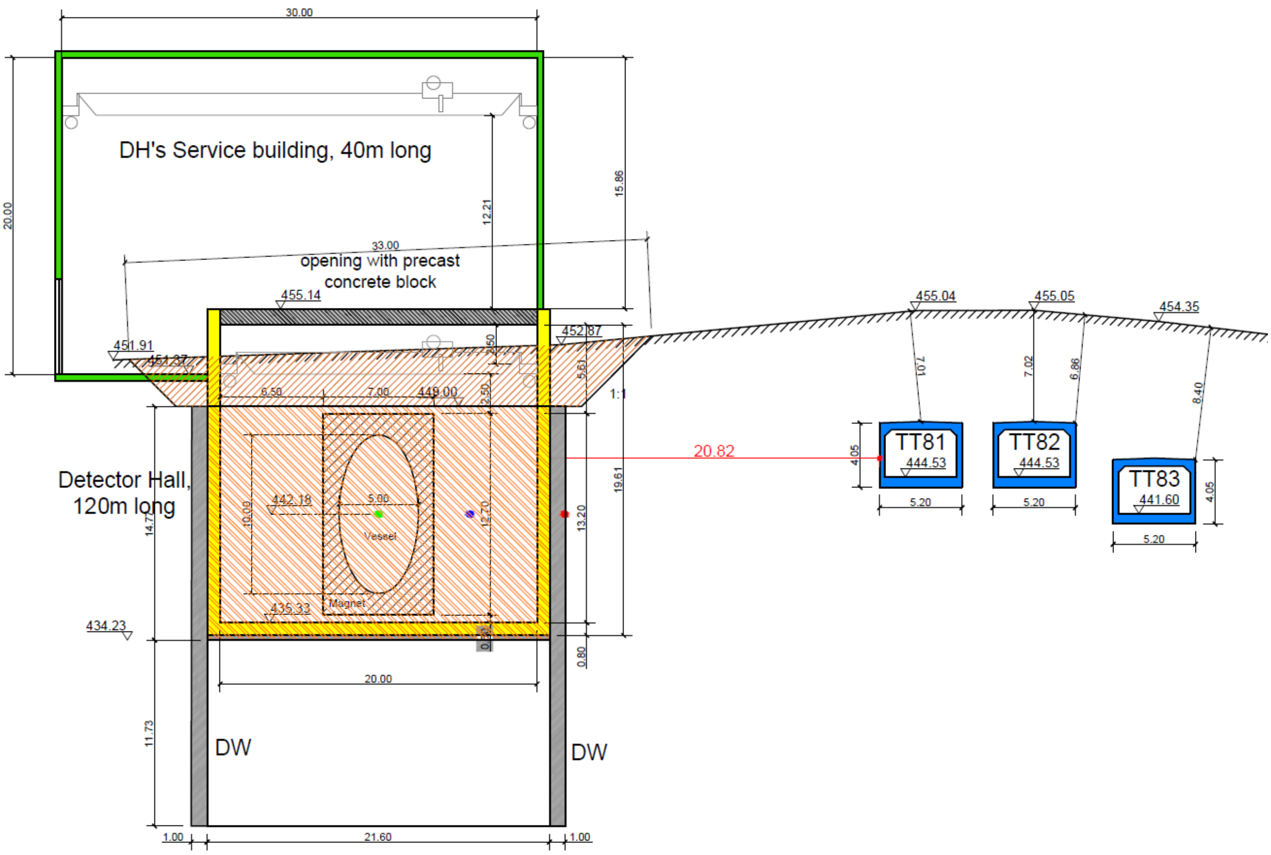

Figure 15: Cross section 9

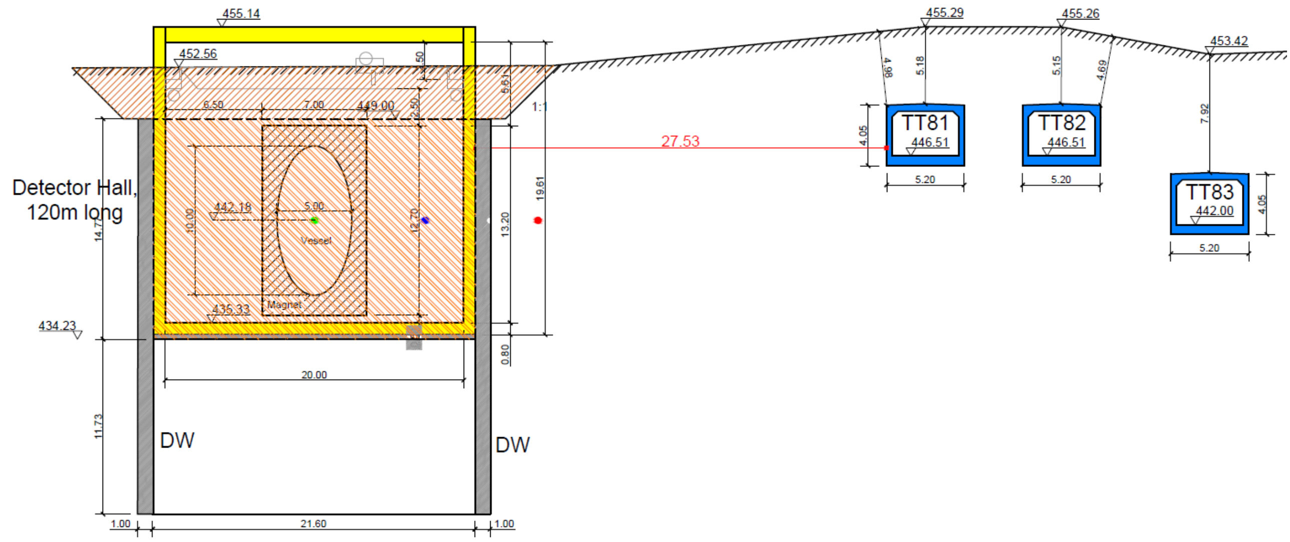

Figure 16: Cross section 10

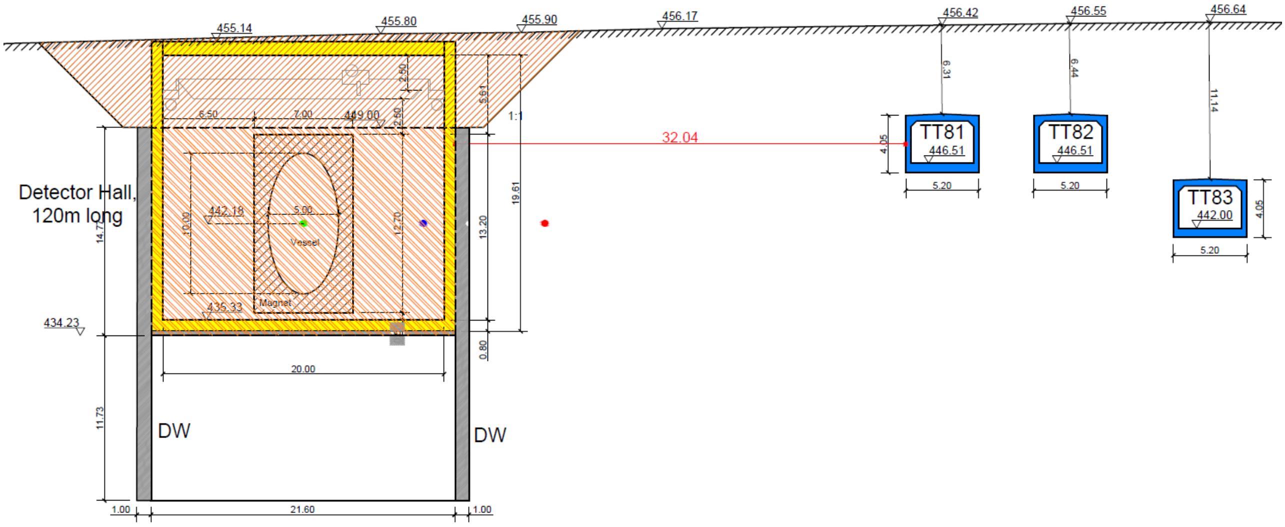

Figure 17: Cross section 11

6.2.6 TDC2 Junction Cavern

The junction cavern consists of an 86 m long new facility in the existing TDC2 complex, providing the starting point for the new extraction tunnel as shown in Figure 18. This will mean that an approximately 100 m length of existing machine and services will have to be removed to allow demolition works of the TDC2 portion to be executed. The impact of the existing concrete and surrounding earth being radioactively contaminated still needs to be fully assessed. Therefore, as the civil engineering works will be in contact with radioactive material and dust, the work procedures and measures to protect the work site must be defined.

The possibility of backfilling the activated demolished concrete and activated earth as the first layer for the new junction cavern and some downstream facilities foreseen for SHiP has been discussed among experts, to avoid disposal off-site and to avoid producing additional activated soil in the future around the facility.

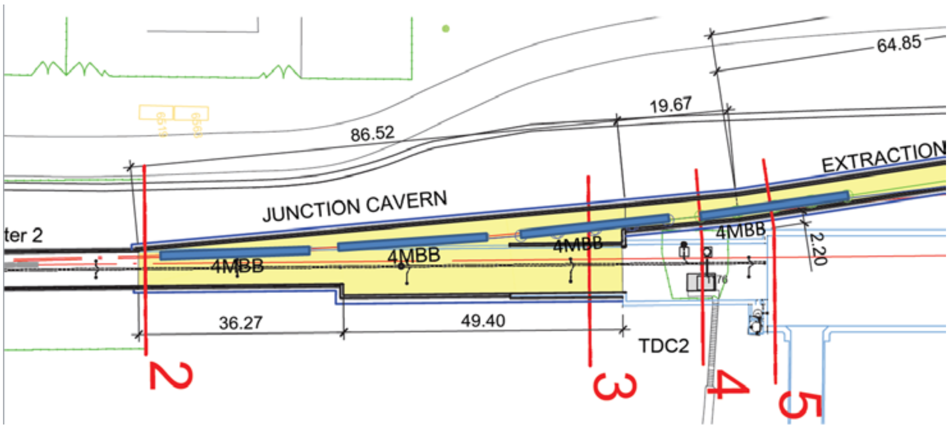

Figure 18: New Junction Cavern in the TD2 complex.

Extra care will have to be taken to ensure that any movement of the existing tunnels is minimised to an acceptable level and no new water ingress problems are created due to the civil engineering works in adjacent structures.

The excavated depth to the invert of the tunnel is approximately 10 m, which means there will be 5.5 m of land fill over the top of the completed structure (see Figure 6 and Figure 7).

6.2.7 Machine Extraction Tunnel

It has been assumed for costing purposes that the internal dimensions of the 166 m long machine extraction tunnel will be 4 m wide by 4 m high (similar to the TDC2 tunnel). This size has been determined by inserting all known machine components / services into a 2D drawing while maintaining free space for transport vehicles and safe passage of personnel.

A machine lattice file was used to determine the alignment of the new tunnel. A steel surface building, including an “Auxiliary Power Supply” area with plan dimension of 10m by 10m, for the ventilation systems and access to the underground structures, equipped with a 40ton crane, is located approximately halfway along the extraction tunnel (see Figure 10).

The floor level of the extraction tunnel is set at a constant 441masl (above sea level), which is same as TCC2 complex.

An emergency egress through a bypass tunnel at the end of the Extraction Tunnel has been foreseen, in order to avoid dead ends, to reach the Service building of the Target Hall located downstream (see Figure 13).

A typical Cross Section for the machine extraction tunnel is shown in Figure 19.

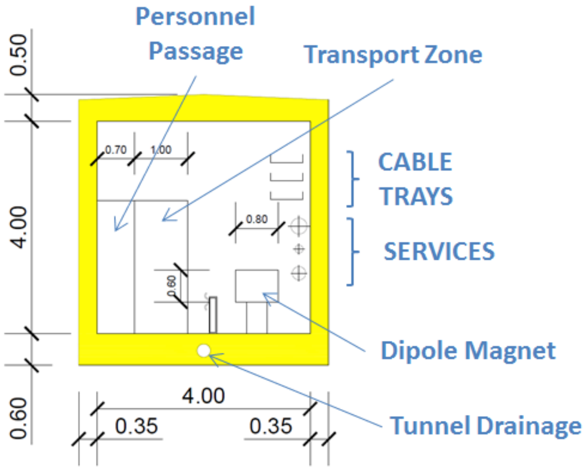

Figure 19: Typical machine extraction tunnel cross section.

6.2.8 Target Complex

The Target Area complex will be characterized by a main hall on surface made in steel frames, equipped with a 40 ton crane, which will have approximate plan dimensions of 40 m by 30 m, as shown in Figure 13 and Figure 20, and a steel service building, on the Jura side, with plan dimensions of 25 m by 15 m. Due to potential radiation contamination, special measures may have to be taken in the target area to minimise the amount of ground water that is able to penetrate the surrounding soils and come in contact with the underground facility.

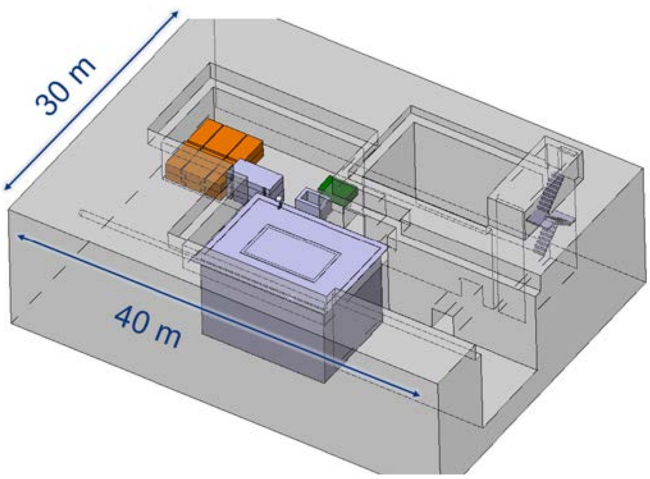

Figure 20: View of the SHiP target complex.

The Target Area complex is also characterized by several underground areas with different size, depth and internal dimensions (i.e. Target Bunker, Muon Shield Tunnel, CV rooms and Storage area). The technical aspects of these areas have been fully described within the TP itself and in other complementary documents.

6.2.9 Detector Complex

The Detector Building will be 120 m long by 20 m wide and equipped with a 40 ton crane.

The floor level of the experiment is set at 435.53 masl. This level was calculated taking into account the beam line level, which remain the same (442.18 masl) along the entire SHIP complex, and the detector volume (vacuum vessel + magnet) around the beam line.

The detector hall will be almost fully underground. A steel surface building (40 m long by 30 m wide) for assembly and installation purposes will be positioned over the first part of the detector hall. This building will be equipped with a 40 ton crane and have an opening, which can be covered with precast concrete beams, providing a vertical access to the underground area.

It is envisaged that a 100m long area could be made available in the future for further developments.

6.3 Cost Estimation for the SHiP Work Packages

The cost estimate for the SHiP Project is based on the layouts presented in this annex. The estimate includes all aspects of construction, final engineering designs and construction management. Many of the rates used to formulate this estimate have been based on real construction costs from LHC experience (1998-2005) and following recent tendering for similar projects at CERN. The overall cost includes:

- 10% Contingency for unknown and missing items
- 20% extra cost for WP1 activities in parallel
- 20% extra cost for additional radiation measures during TDC2 demolition

The civil engineering activities have been split in four different packages as shown in Figure 21.

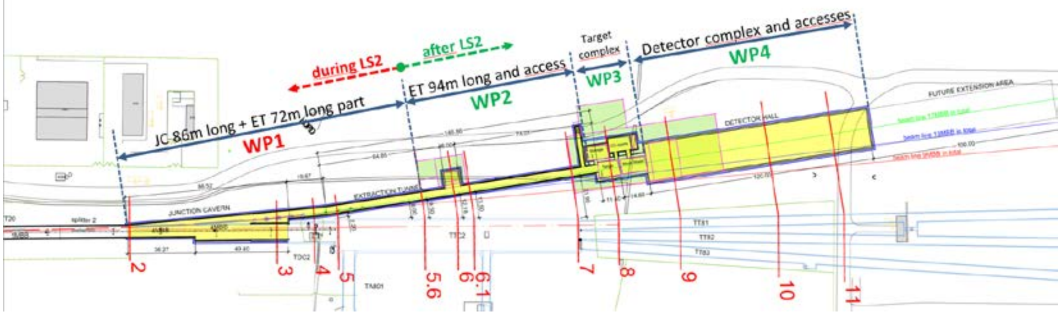

Figure 21: Work Packages identification among the new SHiP underground and surface areas

The provisional cost for the main tasks identified and included within each package is shown in Table 1. The estimated accuracy is ±30%. Not included in this estimate are:

- GS-SE Resources
- Spoil removal off site. It is assumed to be stockpiled on CERN land
- Instrumentation for ground stability monitoring
- Special foundation support for facilities (e.g. Detector, etc)
- Shielding precast concrete blocks
- Infrastructure system (ventilation, electricity, etc)

WP	Main Activity	ID	Task Name	L. (m)	H. (m)	W. (m)	Task Cost (CHF)	Total Cost (CHF)
Work Package 1	1) CE works for **JUNCTION CAVERN** (during LS2)	1.1	Site installation	-	-	-		
		1.2	Excavation up to DW level (449.0m)	86.0	-	-		
		1.3	Diaphragm Walls (DW) *-2 walls-*	172.0	15.0	0.8		
		1.3	Excavation above TDC2 (446.0m)	86.0	-	-		
		1.4	Demolition TDC2	86.0	-	-		
		1.5	Excavation final level (440.0m)	86.0	-	-		
		1.6	Slab with drainage system	86.0	-	12.3		
		1.7	Side concrete walls	172.0	4.0	0.5		
		1.8	Central concrete wall	50.0	4.0	0.5		
		1.9	Roof	86.0	0.6	12.3		
		1.10	Refilling	86.0	-	-		
		1.11	Landscaping, trenches for services..	86.0	-	21.0		
							sub-total:	
	2) CE works for **EXTRACTION TUNNEL** (during LS2), up to section 5.6	1.12	Trees removal	72.0	-	18.5		
		1.13	Excavation up to Sheet piles level (454.0m)	72.0	-	-		
		1.14	Excavation up to DW level (451.0m)	72.0	-	-		
		1.15	Diaphragm Walls (DW) *-2 walls-*	144.0	20.0	0.8		
		1.16	Excavation final level (440.0m)	72.0	-	-		
		1.17	Slab with drainage system	72.0	-	4.7		
		1.18	Side concrete walls	144.0	4.0	0.35		
		1.19	Roof	72.0	0.5	4.7		
		1.20	Refilling	72.0	-	-		
		1.21	Landscaping, trenches for services..	72.0	-	18.5		
	3) Other	1.22	Expert Assistance (12%)	-	-	-		
							WP1, Grand Total:	

Work Package 2	1) CE works for **EXTRACTION TUNNEL** (after LS2), from section 5.6 to section 6.1	2.1	Site installation	-	-	-		
		2.2	Trees removal	26.0	-	18.5		
		2.3	Excavation up to Sheet piles level (454.0m)	26.0	-	-		
		2.4	Excavation up to DW level (451.0m)	26.0	-	-		
		2.5	Diaphragm Walls (DW) *-2 walls-*	70.0	20.0	0.8		
		2.6	Excavation final level (440.0m)	26.0	-	-		
		2.7	Slab with drainage system	26.0	-	4.7		
		2.8	Side concrete walls (ET)	52.0	4.0	0.35		
		2.9	Side concrete walls (PIT)	22.0	10.9	0.5		
		2.10	Roof (ET)	26.0	0.5	4.7		
		2.11	Refilling	26.0	-	-		
		2.12	Access building *(in m2)*	15.0	-	15.0		
		2.13	Crane main rails and support	-	-	-		
		2.14	1 x Main door	-	-	-		
		2.15	Auxillary power supply *(in m2)*	10.0	-	10.0		
		2.16	Landscaping, trenches for services, car park	26.0	-	18.5		
							sub-total:	
	2) CE works for **EXTRACTION TUNNEL** (after LS2), from section 6.1 to end	2.17	Trees removal	68.0	-	20.3		
		2.18	Excavation up to level (457.0m)	34.0	-	-		
		2.19	Excavation up to level (453.0m)	68.0	-	-		
		2.20	Excavation up to DW level (449.0m)	68.0	-	-		
		2.21	Diaphragm Walls (DW) *-2 walls-*	160.5	16.0	0.8		
		2.22	Excavation final level (440.0m)	68.0	-	-		
		2.23	Slab with drainage system	68.0	-	4.7		
		2.24	Side concrete walls (ET)	136.0	4.0	0.35		
		2.25	Side concrete walls (escape way)	42.0	2.2	0.30		
		2.26	Roof (ET)	68.0	0.5	4.7		
		2.27	Roof (escape way)	21.0	2.8	0.40		
		2.28	Refilling	68.0	-	-		
		2.29	Access building for escape way *(in m2)*	3.0	-	7.0		
		2.30	Landscaping, trenches for services..	68.0	-	20.3		
							sub-total:	
	3) Other	2.31	Expert Assistance (12%)	-	-	-		
							WP2, Grand Total:	

Work Package 3	1) CE works for **TARGET AREA** (after LS2)	3.1	Trees removal	30.0	-	34.0		
		3.2	Excavation up to DW level (447.5m)	30.0	-	-		
		3.3	Diaphragm Walls (DW) *-right side-*	31.5	18.0	0.8		
		3.4	Diaphragm Walls (DW) *-left side (1/2)-*	13.2	18.0	0.8		
		3.5	Diaphragm Walls (DW) *-left side (2/2)-*	22.0	18.0	0.8		
		3.6	Excavation final level (443.1m), cast storage	13.2	4.4	10.0		
		3.7	Excavation final level (440.1m), cv room	17.0	7.4	10.0		
		3.8	Excavation final level (438.0m), bunker, MS	27.0	9.5	11.5		
		3.9	Slab with drainage system	30.0	-	22.0		
		3.10	Side concrete walls (cast storage)	16.0	7.0	0.50		
		3.11	Side concrete walls (cv room)	49.0	10.0	0.50		
		3.12	Side concrete walls (bunker, MS//down)	55.0	9.0	1.50		
		3.13	Side concrete walls (bunker, MS//up)	55.0	3.5	1.00		
		3.14	horizontal connections (cv-MS, cv-bunker)	-	-	-		
		3.15	Refilling	30.0	-	-		
		3.16	Service building *(in m2)*	25.0	-	15.0		
		3.17	Target Hall *(in m2)*	40.0	-	30.0		
		3.18	Crane main rails and support	-	-	-		
		3.19	1 x Main door	-	-	-		
		3.20	Fast water drai system	-	-	-		
		3.21	Excavation "open-cut" TG	140.0	4.0	8.0		
		3.22	Side walls&slabs TG	140.0	-	-		
		3.23	Refilling	140.0	-	-		
		3.24	Landscaping, trenches for services, car park	30.0	-	34.0		
							sub-total:	
	2) Other	3.25	Expert Assistance (12%)	-	-	-		
							WP3, Grand Total:	

Work Package 4	1) CE works for **DETECTOR AREA** (after LS2)	4.1	Site installation	-	-	-		
		4.2	Trees removal	120.0	-	33.0		
		4.3	Excavation up to DW level (449.0m)	120.0	-	-		
		4.4	Diaphragm Walls (DW) *-2 walls-*	270.0	26.5	0.8		
		4.5	Excavation final level (434.2m)	120.0	-	-		
		4.6	Slab with drainage system	120.0	-	21.6		
		4.7	Side concrete walls	270.0	20.0	0.8		
		4.8	Roof (DH)	120.0	1.0	20.0		
		4.9	Crane main rails and support	-	-	-		
		4.10	Refilling (...lateral)	140.0	-	-		
		4.11	Service building *(in m2)*	40.0	-	30.0		
		4.12	Crane main rails and support	-	-	-		
		4.13	1 x Main door	-	-	-		
		4.14	Access building *(in m2)*	5.0	-	5.0		
		4.15	Landscaping, trenches for services, car park	120.0	-	33.0		
							sub-total:	
	2) CE works for **ACCESS ROAD** (after LS2)	4.16	Route du Jura deviation + new access	350.0	-	7.0		
							sub-total:	
	3) Other	4.17	Expert Assistance (12%)	-	-	-		
							WP4, Grand Total:	
	1) **SITE INVESTIGATION**	5.1	core drilling, soil test, etc..	-	-	-		
							SHIP Civil Engineering WPs, Grand Total:	
							10% Contingency:	
							20% extra cost for WP1 activities in parallel:	
							20% extra cost for additional radiation measures during the TDC2 demolition:	
							SHIP Civil Engineering OVERALL COST:	

Table 1: Civil engineering cost estimate for SHiP facility

The annual cost forecast is indicated in Figure 22. The cost per year has been split between the “civil engineering works” related to the construction phase and initial site investigation and the “expert assistance” that in fact cover the entire civil engineering process starting in 2016.

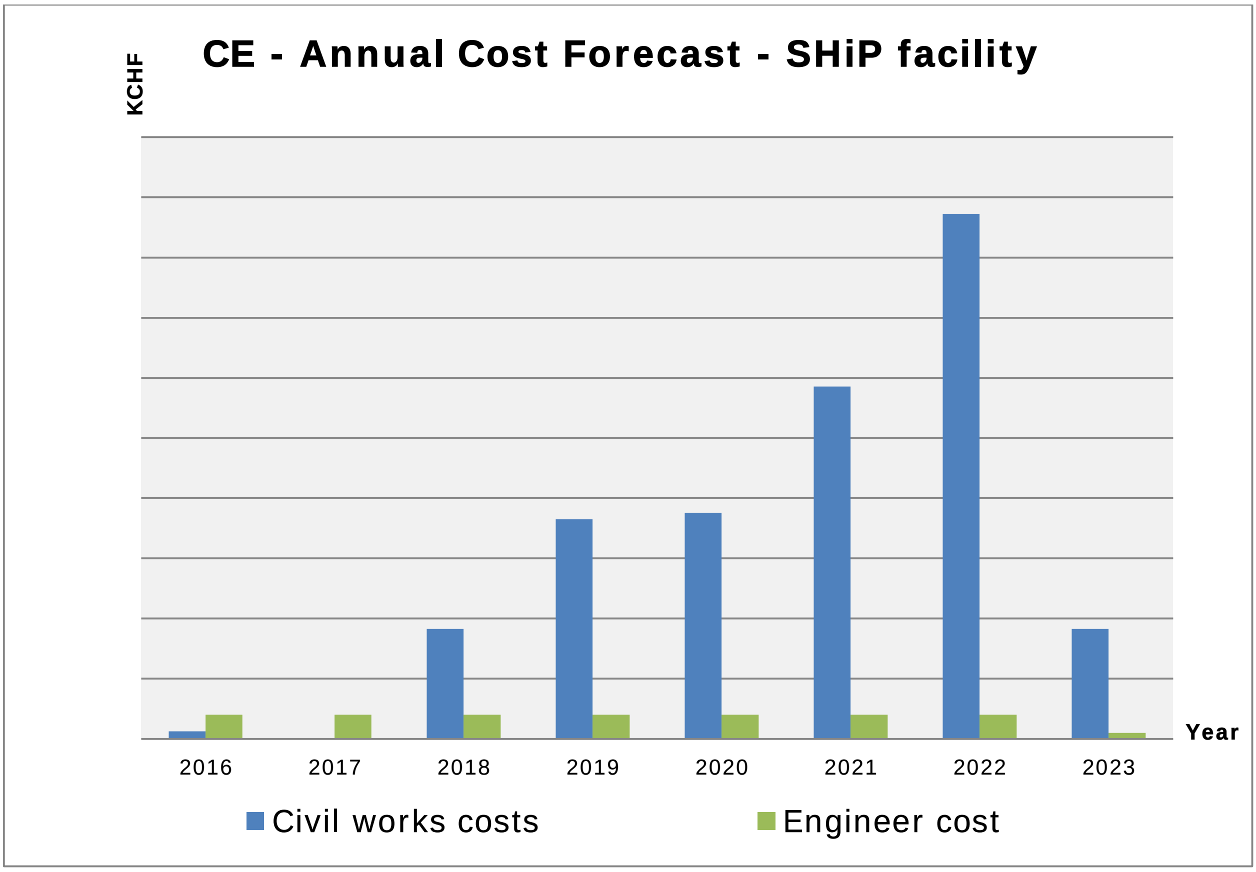

Figure 22: Civil engineering annual cost forecast

6.4 Schedule and Resource Considerations

A preliminary schedule has been studied for the construction of the SHiP facility using the knowledge acquired from the construction of previous similar schemes at CERN. This timeline is shown below in Figure 23.

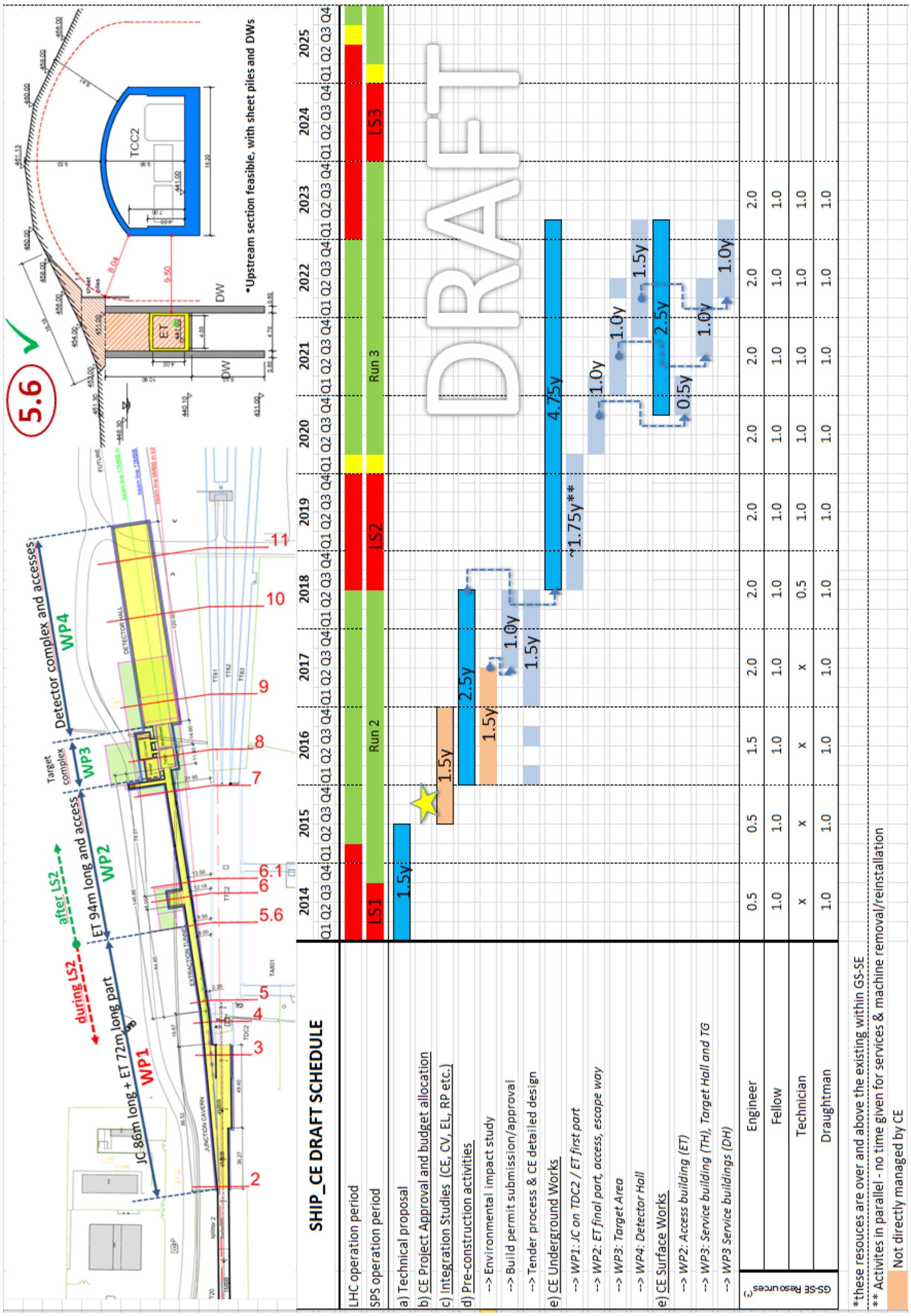

Figure 23: Civil engineering planning for SHiP facility

A detailed integration study with all concerned parties needs to be completed prior to start of the detailed civil engineering design. This involves setting up a dedicated Integration team looking at all aspects of the project (beam line, Detectors, HVAC, electricity, transport, RP, safety, access etc.). Once these integrated concept drawings are approved, civil engineering can start detailed design with external design specialist companies. Once these designs are complete, tendering for the civil construction contracts can start.

In parallel, an environmental impact study must be prepared and approved by the local authorities, prior to the timely submission of the building permit for the project, to allow construction works to commence.

The CE works are split in four packages, as indicated within the cost evaluation.

WP1 is for all the activities that must be carried out during LS2 (i.e. Junction Cavern and Extraction Tunnel up to Section 5.6, Nevertheless the 21 months indicated for the LS2 are very compressed especially when taking into account activities such as the machine cool-down, infrastructure dismantling/reinstallation and special radioactive concrete and soil treatment.

WP2, WP3 and WP4 activities will start after the LS2 (construction works can be performed during normal beam-operation of the North Area, where the required 8 m of soil separation between new and existing structures is guaranteed, for safe beam-operation). WP2 requires 12 months for the Extraction Tunnel completion and its surface accesses. WP3 for the Target Area complex needs 18 months as well as WP4 for the Detector complex. In principle, these work packages could be partially executed in parallel, although this needs to be studied in more detail.