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An Experimental Area for Short Baseline Neutrino Physics on the CERN Neutrino Beam to Gran Sasso

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Abstract

A new neutrino beam line from the CERN SPS to the Gran Sasso laboratory in Italy is presently under study. The new neutrino beam will allow both long baseline and short baseline neutrino oscillation experiments to be performed. This report presents a conceptual design of the short baseline experimental area to be located at a distance of 1858 m from the neutrino target.

Contents

1 Introduction

This report describes the conceptual design of an experimental area for neutrino physics. The area is intended for a short base line (SBL) neutrino oscillation experiment on the recently proposed CERN Neutrino beam to Gran Sasso (NGS) [1]. The CERN NGS beam is directed towards the Gran Sasso laboratory, an underground laboratory in central Italy, 732 km away from CERN. This new neutrino beam will be a tool to perform both long base line (LBL) and short base line (SBL) neutrino oscillation searches. The SBL experiment will be sensitive to small mixing angles $\sin^2 2\theta$, whereas the LBL experiment will address low neutrino mass differences squared Δm^2.

The neutrino beam, predominantly ν_μ, will be created through decays of charged π and K mesons produced by protons extracted from the SPS accelerator and striking a graphite target. The produced mesons will be focused by the magnetic field of a horn and reflector system. A 1000 m long decay tunnel will allow for part of the π's and K's to decay in flight. A hadron stop will absorb the non-interacting primary protons as well as the remaining secondary hadrons. The natural shielding provided by 707 m of molasse will absorb most of the muons from meson decays upstream of the SBL detector. The SBL site will be situated at 1858 m from the proton target. As the direction of the beam will be pointing to the Gran Sasso laboratory, this implies that the beam centre is situated at a depth of 151 m underground at the location of the SBL site.

A letter of intent (LOI) for a SBL experiment has been submitted to the SPSC committee in March 1997 [2]. Although this experiment was initially planned for the existing West Area Neutrino Facility (WANF), it is compatible with the new CERN NGS beam [3]. The experiment carries the name TOSCA for Topological Oscillation Search using kinematiCal Analysis. The experiment searches for ν_τ appearance in a predominantly ν_μ beam. The ν_τ will be detected through Charged Current (CC) interactions followed by τ^- decay. The instrumented target of the experiment consists of a modular spectrometer located in a magnetic volume of $3.5\times3.5\times7$ m^3. Each of the 5-6 modules consists of an emulsion target followed by silicon trackers, emulsion trackers and wire chamber trackers. The combination of the emulsion targets and the precise trackers in a single magnetic volume will allow for the identification of the kinematic signature of ν_τ interactions at the same time as the detection of the τ^- decay kink. The magnetic volume will be provided by the MEP50 magnet, presently in use by the NOMAD experiment [4], and previously used by the UA1 experiment [5]. Behind the magnet, a muon detection system will be placed. The conceptual design of the SBL facility is based on the requirements of the LOI mentioned above [2, 3].

The paper is organised as follows. Section 2 will summarise the neutrino beam parameters at the SBL site. Section 3 will describe the outer layout of the experiment as well as the main infrastructure requirements. In section 4 the civil engineering layout of the site will be discussed. Section 5 to section 10 will subsequently describe the infrastructure systems foreseen for, heavy handling and elevators, cooling and air conditioning, electrical power, site access, fire and gas detection and gas distribution. Conclusions will be drawn in section 11. The civil engineering figures will be collected in Appendix A. A summary of the cost estimates is presented in appendix B. The safety aspects of the design will be discussed, where applicable, in the various chapters.

2 Design and performance of the NGS beam at the SBL site

The design of the NGS beam is extensively described in the NGS report [1]. Only a brief summary of the design and performance will be given here.

- The CERN NGS beam is derived from a primary proton beam of up to 450 GeV, extracted in two fast ejection cycles, 10 μs, striking a segmented graphite target.
- The secondary mesons are collimated and focused by a classic horn and reflector system pointing to the Gran Sasso laboratory.
- Part of the π and K particles decay in a 1000 m long decay tunnel, thereby producing an intense neutrino beam principally composed of ν_μ particles.
- Non-interacting primary protons as well as secondary hadrons, which have not decayed, are absorbed in an 18 m long stack of graphite and iron blocks, the hadron stop.
- The remaining muons from hadron decays are detected in a muon monitoring station composed of 2 planes of silicon detectors. The first plane is located just after the hadron stop and the second plane is located further downstream after 67 m of molasse. Measuring the muon intensity and profile provides information on the intensity, focusing and profile of the neutrino beam.
- A length of 640 m of molasse separates the second muon station from the SBL experimental cavern.

A schematic drawing of the main components of the beam and decay tunnel is given in Fig. 1. The location of the NGS beam with respect to the SPS and LHC rings is shown in Fig. 2 and a vertical cut along the beam line, showing the relative depth of the main components and the SBL detector, is shown in Fig. 3.

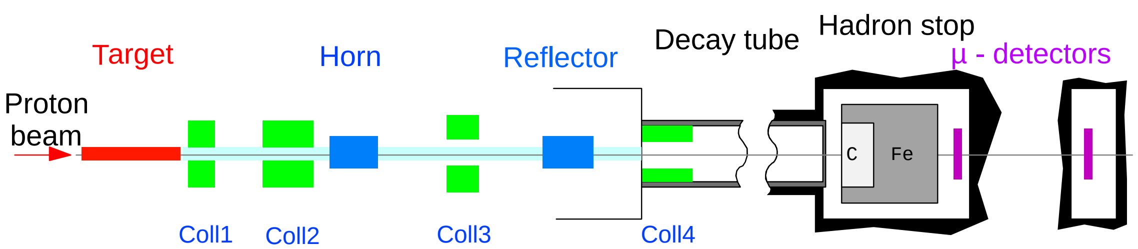


Figure 1: Schematic layout of the CERN NGS beam line, indicating its principal elements.

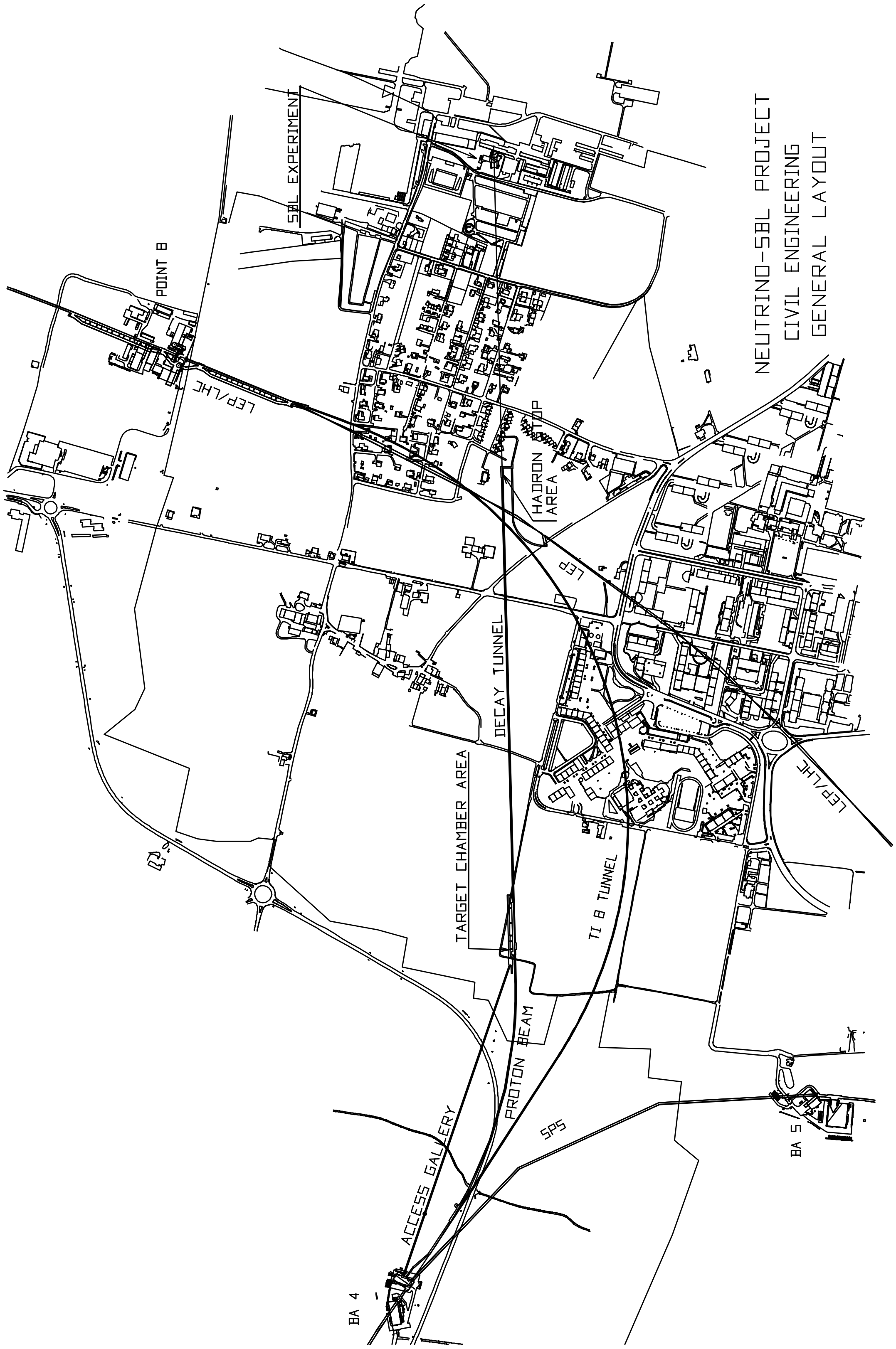


Figure 2: Aerial view of the CERN NGS beam line and of the SBL experimental site, indicating their locations with respect to existing CERN facilities.

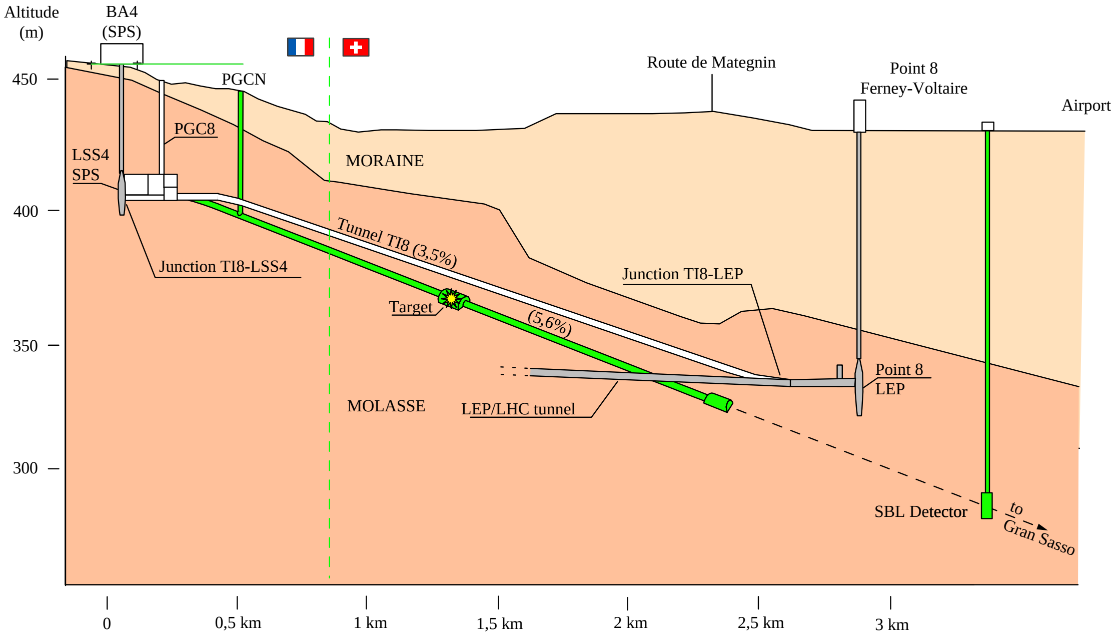


Figure 3: Vertical cut of the CERN NGS beam line.

2.1 Neutrino spectrum and event rate at the SBL detector

A reference version of the NGS beam, suitable for both the SBL and LBL experiments, has been extensively simulated by several independent Monte Carlo programs. There is good agreement between the various programs and the expected fluxes and event rates are presented below. It must be stressed, however, that this reference beam was defined to show the constraints on the design and to give a comparison of the different programs. It is reasonable to expect that an optimization of the target structure and the focusing conditions will provide significantly better fluxes.

The ν_μ energy distribution of the reference beam is shown in Fig. 4 for the SBL experiment, integrating over a 1.44×1.44 m^2 surface. The expected event rates are given in Table 1.

	SBL detector
ν_μ [m^{-2}/pot]	1.55×10^{-3}
mean ν_μ energy [GeV]	24.6
ν_μ CC events/pot/ton	1.55×10^{-14}
ν_μ CC events/year/ton	4.65×10^{5}

Table 1: Predicted performance of the ν_μ component of the NGS ‘reference beam’, where pot stands for ‘protons on target’.

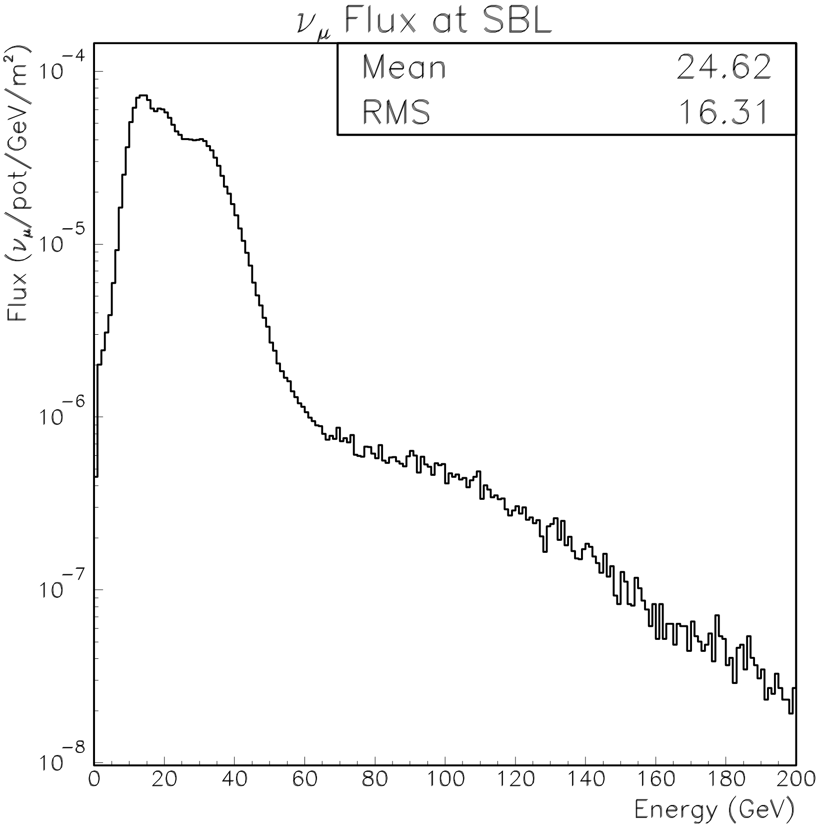


Figure 4: The ν_μ energy distribution of the reference beam.

2.2 Muon background at the SBL experimental area

There are two kinds of muon background that must be considered at the SBL experiment:

- muons coming from neutrino induced reactions in the material in front of the detector,
- muons coming from hadrons decaying in the decay tunnel and punching through, or multiple scattering around the shielding material in the hadron stop area.

The first case is an irreducible background that cannot be avoided. Adding or taking away material makes little difference as the neutrino interactions and muon fluence are in equilibrium.

A fairly straightforward calculation indicates an incident muon background from nearby neutrino interactions, at the front wall of the SBL cavern of 2.5 muons per m^2 for 10^{13} protons on target. The prediction of the direct muon penetration from the beam is a more difficult calculation, but the overall stopping power of the 18 m hadron beam stop and the 707 m of molasse, 181.2 kg/cm^2 in total, should be sufficient to reduce the muon punch through to less than the neutrino induced background [1].

3 Outer layout of TOSCA and its infrastructure demands

The outer dimensions of the experiment are principally defined by the spectrometer magnet MEP50 and by the muon detection system. The layout is depicted in Fig. 5. The main characteristics of the MEP50 magnet are summarised in Table 2.

Field volume	$3.5\times3.5\times7$ m^3
Maximum field	0.7 T
Maximum current	10000 A
Power consumption at max. field	5.55 MWatt
Cooling water flow	180 m^3 /hr
Cooling water pressure drop	17 Bar
Temperature of water inlet	52 °C
Temperature of water outlet	26 °C
Total weight	1400 t
Height of the field volume centre	4.87 m above floor

Table 2: Characteristics of the MEP50 magnet

It is foreseen to use the magnet at its full field of 0.7 T. The total weight of the magnet is determined by the iron return yokes. The yokes are arranged in fixed front and back parts, the so-called I's, and moveable transversal parts, the so-called C's, which allow access to the magnetic volume. The sixteen C's are more bulky than the I's. They weigh 55 t each and form the heaviest non-dividable units of the experiment. The four aluminium magnet coils fit into the yoke structure formed by the C's. These coils form the largest elements of the experiment ($4\times7.75\times0.9$ m^3), with individual weights of up to 9.7 t. The coils are normally transported upright.

The main heavy handling demands of the TOSCA experiment are determined by the C’s and the coils of the magnet. The 5.55 MWatt power dissipation of the magnet calls for the corresponding infrastructure in terms of electrical power and water-cooling. However, the use of the MEP50 magnet is not a limiting factor. Any sizeable experiment would require similar facilities. The safety requirements related to the deep underground location, isolated from any other CERN site, also put heavy demands on the infrastructure.

The target of the TOSCA experiment will be composed of 5-6 emulsion stacks placed inside the magnet and distributed along the beam axis. These emulsion stacks, with a total weight of 2400 kg, have to be kept under very precise temperature and humidity controlled conditions. Any temporary loss of temperature or humidity control would mean a dramatic loss of information of the tracks recorded in the emulsion. A coolbox, intended to maintain the emulsion at a temperature stability of 5 °C ± 0.5 °K and a humidity of (55 ± 5) %, is part of the cooling infrastructure described in Section 6.

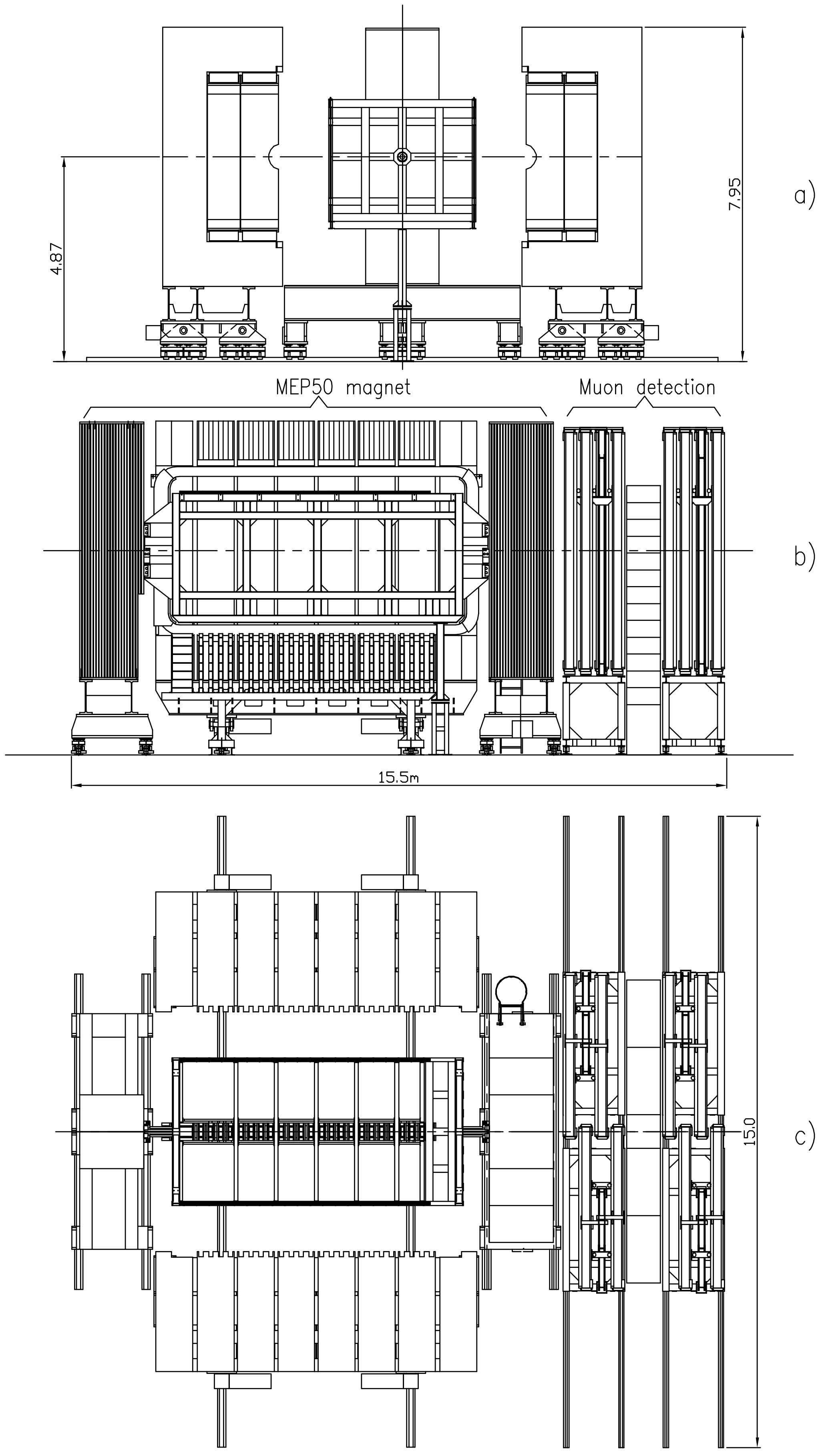


Figure 5: Outer layout of the TOSCA experiment: a) transversal cross section of the magnet, b) longitudinal cross section of the experiment, c) top view of the experiment.

4 Conceptual Technical Design

4.1 Introduction

The experimental cavern representing the main part of the civil engineering project is destined to house the "Near Detector". The design of the cavern presented here is adapted to the dimensions of the TOSCA experiment. As far as civil engineering is concerned, the "Near Detector" project is totally independent of the NGS project. This implies that the project can start at any time, after the necessary approvals and budgets have been secured. The status of the project as described here is the one defined in May 1998 by the relevant Working Group and endorsed by the CERN Neutrino Internal Committee.

The project is approached in this chapter from two distinct points of view: first, a description of its various parts, referring to the main geometrical parameters is given. Then an account is provided of the working methods and equipment to be used to successfully complete the project.

4.2 Description of the project

The civil engineering project is subdivided into three parts:

1. the experimental cavern
2. the access shaft
3. the surface buildings

The centre of the TOSCA experiment, to be housed in the experimental cavern, is aligned on the neutrino beam directed to the Gran Sasso laboratory. The distance along the beam between the last wall of the second muon detector chamber of the NGS facility and the centre of the TOSCA experimental cavern is 660 m. The centre of the TOSCA target is located at 1858 m downstream of the neutrino target. The depth of the experimental cavern is a direct consequence of the -5.62% slope of the neutrino beam. At the centre of the TOSCA target, the beam passes at 151 m underground.

As in the case of the NGS project, the underground structures for TOSCA will be excavated almost entirely in solid rock, which is Leman basin molasse. This rock consists of variable quality strata ranging from relatively soft marls to very hard sandstones. The methods, means of excavation and support have been suited to this type of rock, as described in section 4.3 below. The sole exception is the access shaft, via which the underground civil engineering will be carried out. Its upper section passes through about 70 m of water bearing moraines and gravels with a layer of silty watertight moraine in between (see section 4.3.3 and Fig. 3). A cylindrical shape is foreseen for the underground structures, as this is economically the best suited for the type of soil.

The area of land, which has been selected for the surface buildings, is situated between the Meyrin cemetery and the Geneva Airport facilities. It is situated at a distance of some 300 m from the main runway of the Airport, which implies that the surface buildings will have to comply with restrictive standards as regards their overall height. Despite its small total surface of about 3000 m^2, this particular plot of land presents several assets:

- taking into account the situation of the airport, it is as far away as possible from the neutrino target and therefore optimised for muon background absorption;
- its availability for the TOSCA project should not prove too difficult as it presently belongs to the airport, which has apparently no intention to use it in any way;
- the roads leading to it are in good condition and are well connected to the Meyrin network, although they are rather narrow.

The sizes given in the following descriptions are the final internal dimensions, which define the actual available space. For the excavation diameters, the dimensions must be increased by 0.6 m to 1.0 m, to allow for the thickness of the temporary support and the final lining. This does not apply to the surface buildings, where the external dimensions are given. All civil engineering figures, referred to in this section, are assembled in Appendix A.

Experimental cavern

The experimental cavern has a cylindrical shape and is 40.0 m long, with a diameter of 21.20 m. Its two headwalls are curved in the horizontal plane in order to economically withstand the rock pressure. The thickness of the cavern floor slab is about 4.0 m. The internal cavern height is 17.0 m. Its walls and vaults will receive a cast *in-situ* concrete lining.

A top view of the experimental cavern is shown in Fig. 6 and Fig. 7 of Appendix A. It shows the TOSCA experiment with open magnet on the right (east) and the access shaft on the left (west). The neutrino beam enters from the left. A transversal cross section of the cavern is depicted in Fig. 8. A longitudinal cross section is shown in Fig. 9. In this figure the trajectory of the neutrino beam is drawn. It passes the centre of the experimental target at 4.87 m above the floor.

The cavern will receive steel structures on both sides, which bear the weight of a 10 t overhead crane for heavy handling. Horizontal access platforms at two different levels will be installed on both sides of the experiment. These platforms will house small installations, like gas detection and magnet electronics. A two-story counting room will be installed on the south side. A two-story concrete structure on the north side will serve as a service room for housing air conditioning, cooling and electrical equipment.

Access shaft

The access shaft from the surface will be connected to the western end of the experimental cavern. It is 156 m deep to the floor of the experimental cavern, with a diameter of 10.0 m. The shaft will receive a cast *in-situ* concrete lining. It is designed to house two lifts, two staircases and a material access shaft (trémie) for lowering equipment. In addition the shaft will be fitted with cable trays, ventilation ducts and pipes of various diameters. A cross section of the access shaft is shown in Fig. 10. After completion of the work, a permanent protection will be mounted on top of the access shaft for reasons of safety and ventilation control.

Surface buildings

The surface buildings are situated as close as possible to the access shaft for two main reasons:

- this constitutes the most economical solution as regards civil engineering as well as the services themselves;
- the small dimensions of the available land do not allow any spreading of the surface facilities.

Fig. 11 shows the layout of the surface facilities of the project. The dotted shape near the SUX building depicts an existing wooden structure that will need dismantling. Fig. 12 shows an aerial view of the site, including the existing roads and buildings in its vicinity. The access links between the surface buildings and the existing road on the western side of the site are properly taken into account, with slopes that are compatible with CERN's means of transportation and handling.

SX building

The SX hall is situated above the access shaft. Hence it will accommodate all the necessary equipment for the transit of equipment and of personnel to the underground experimental area.

The building has a steel superstructure – steel frame, steel cladding and roof – fixed over concrete foundations and a general slab. The walls and roof of this building will be thermally insulated. Its steel frame will be designed to receive a 10 t overhead crane. Its dimensions are 23.0 m in length, 13.0 m in width and 11.0 m in height. The south wall of the SX hall (against the SR and SE buildings) will be in concrete.

SUX building

This building is destined to house the cooling and ventilation equipment and stands against the eastern wall of the SX building. The layout and equipment of the SUX building are depicted in Fig. 13 of Appendix A. Owing to its noisy installations the building is designed as a "concrete box" of the same type as those already existing on LEP sites. The thickness of its concrete walls will be at least 30 cm. Its roof is composed of a concrete slab, at least 25 cm thick, resting on prefabricated or prestressed concrete beams. This three-story building has a trapezoidal shape with a long base of 16.0 m, a short base of 11.8 m, a width of 12.3 m, and a total height of 12.0 m. At the northern face of the building three transformers on concrete pits are foreseen.

SCX building

This building will house the control room, a workshop, space for computer equipment and ancillary facilities such as toilets, a cloak room and storage space. It is designed as a traditional masonry building with windows as required, and the necessary thermal and noise insulation material. It is 16.7 m in length, 10.5 m in width and 4.5 m in height. It stands against the northern face of the SX building, close to the access shaft. The space between the SCX building and the SX building is used as a transit room for personnel access to the lifts and staircases at the top of the access shaft.

SE building

This building will house the electrical power distribution equipment. It is constituted of a steel frame on which prefabricated “sandwich type” concrete panels are fixed. It stands on top of traditional concrete foundations. Its shape is close to rectangular, with dimensions of 10.0 m in length, 8.5 m in width and 4.5 m in height. The electrical equipment is fixed on a false floor.

SR building

This building will house the power converters for the magnet of the experiment. Its dimensions are 10.0 m in length, 4.0 m in width and 4.5 m in height. Its structure is the same as for the SE building. At the western end of the building a transformer on a concrete pit is foreseen.

SGX building

This building will house the gas mixing facilities for the TOSCA tracking detectors. It measures 7.0 m in length, 5.50 m in width and 4.50 m in height. It is a steel structure or ready bought barrack standing on concrete foundations. About 1/3 of its surface is composed of a shed structure under which gas batteries are placed. A blow-off roof will cover this building.

4.3 Working methods

4.3.1 General

Due to the proximity of the airport runway and buildings, and given the preliminary status of the project, no geotechnical investigations of the ground have been performed. Therefore, the proposed working methods, material resources and performance sequences of the works are based on our knowledge of the underground characteristics acquired during the LEP works at Point 8. The vicinity of the two sites (about 900 m) and a certain similarity in the underground structures (shaft and experimental cavern) justifies this approach. Of course, in order to prepare tender documentation, the relevant design parameters should be based on at least one investigation boring, to be carried out at the location of the access shaft.

Unlike the LHC and NGS projects, the TOSCA project does not interact with any CERN existing structure, which will greatly ease the execution of the work. The only drawback is linked to the presence of the nearby airport facilities, and the various constraints and authorizations that will entail.

4.3.2 Material resources

The material resources to be used by the contractor for the work should be:

- for excavating the access shaft: rock breaker, point-action machines (roadheaders), dumpers, tower crane or gantry crane at the surface (the use of explosives is not allowed in this area), a complete set of equipment for the ground freezing if necessary,
- for excavating the underground cavern: roadheaders, dumpers, tower crane or gantry crane at the surface,

- for the concrete linings: one or more heavy-duty shotcreting machine and a set of curved shuttering with pumps and pipes for transporting the concrete.

All the equipment described above will be suggested in the specifications of the call for tenders for the works. As usual, bidders are free to propose equipment of the type, which is more available to them, or more suited to their own working methods, in accordance with the proposed time schedule.

4.3.3 Work sequences

Excavation of the access shafts

The supposed presence in the ground of two water tables at two different levels (-20 m and –45 m) implicates the selection of methodologies of the same kind as those successfully used for Point 8 of the LEP project or ground freezing as an alternative:

- from 0 to about –35 m: execution of a waterproof concrete diaphragm wall, with a diameter of about 12 m, through water bearing moraines;

- from –35 m to –70 m: execution of a “paroi marocaine” composed of a succession of concrete rings one under the other downwards. This “paroi marocaine” will pass through a waterproof layer of ground, then between –45 m and –70 m through a water bearing slice of ground, mainly composed of gravels;

- from –70 m to –130 m: excavation of the molasse rock with roadheaders or rockbreakers, together with the usual temporary support. This support is placed while the excavation work progresses downwards and is composed of bolts, mesh and shotcrete.

Excavation of the experimental cavern

At first, a widening will be created at the bottom of the access shaft to house the necessary technical facilities and space for the actual starting of the excavation works. The whole of the experimental cavern will be excavated in successive layers with one or two roadheaders, with the help of traditional excavation equipment and spoil handling. As soon as possible the excavated rock faces will be protected with the same temporary support as mentioned for the access shaft.

Concreting

The final concrete linings of the structures are to be carried out as follows:

- for the access shaft, a curved shuttering, which could be of a sliding type, thus allowing a non-stop concreting of the lining of the shaft. This technique was successfully used in the case of all LEP shafts. The concrete will be pumped through pipes from the surface (batching plant or ready made concrete);

- for the experimental cavern, the concreting of the various areas will be undertaken in the following sequence: floor (first phase), both sides, vault including connection to the base of the shaft, headwalls, floor (second phase). As usual, the sides and vault will be dealt with as two distinct phases. As for the shaft, the necessary concrete will come from the surface.

Erection of the surface buildings

All foundation works will be carried out with concrete poured into trenches, with the necessary steel reinforcements. Then the concrete buildings (SUX and possibly SCX) will be erected using cast *in situ* concrete, and possibly some precast concrete elements. For the other buildings (SX, SR, SE), a steel structure will be set up on the concrete foundations. This steel structure will then receive insulated steel double cladding (sandwich type concrete panels for SE and SR) for the walls, steel sheets with insulation material and waterproofing membrane for the roof.

4.3.4 Work duration and organization

Although no starting date is fixed, an estimate of the work duration for the three main phases of the project can be given. Excavation and concreting durations are assessed to 9 to 10 months for the access shaft and 10 to 14 months for the experimental cavern. The construction of all surface buildings is expected to take about 10 months. Hence the overall duration of the civil engineering works would be in the order of 32 to 36 months including some contingencies.

As for the LHC and NGS projects, one should start with the selection of a reliable and available consultant, to perform design phases as well as site supervision. In the process of the design phase, the consultant should prepare the technical part of the call for tenders for the works, likely to be sent in countries contributing to the budget of the project. Then a contract would be placed, and works carried out, by the contractor having put forward the cheapest technically fully satisfactory offer.

In the same respect, a safety consultant would be selected to play the role of the safety coordinator through all phases from preliminary design to final acceptance, in compliance with the new European Directives.

5 Heavy handling and elevators

5.1 Heavy handling

For the design of the heavy handling equipment a number of parameters and objectives have been taken into account:

- the dimensions and weights of the specific elements of the TOSCA experiment that are most critical in terms of handling (heaviest weights or largest dimensions). A list of these elements is given in Table 3. All other elements are lighter as well as smaller.

- the height of the SX surface hall. Taking into account the proximity of the airport runway, an imposed height limitation of around 7 m can be expected for this building. Any additional height will imply a lowering of the floor level, which will entail budgetary consequences as well as difficulties for the access of trucks.

- cost-effectiveness. In particular, temporary solutions in the form of rental cranes and exchangeable air cushions have been chosen for the handling of the heaviest elements. This avoids the permanent installation of heavy overhead cranes that would only be used during very limited time periods (the installation and dismantling phase).

Element	**Number of pieces**	**Weight (t)**	**Height×Length×Width (m^3)**	**Comment**
Magnet C-yoke	16	55	6.15×2.85×0.88	
Magnet I-yoke	8	40	6.15×1.40×0.88	
Support of C-yokes	2	<5	1.75×7.65×2.45	
Support of I-yokes	4	<5	1.75×2.80×2.00	
Magnet coils	4	9.7	4.00×7.75×0.90	to be transported upright
Muon chambers	8	2-3	6.00×4.00×0.25	

Table 3: Elements of the TOSCA experiment that are most critical in terms of transportation (heaviest weights or largest dimensions). The dimensions of the handling supports are not included in the Table.

The installation of the heavy elements of the MEP50 magnet will be performed after the completion of the experimental cavern and the access shaft, but before the completion of the walls and the roof of the SX surface hall. The installation sequence proceeds as follows:

- A long-range rental crane with a 400 t capacity and a telescopic arm of 31 m length will be installed in the corner between the SUX and SX buildings.
- The support of the downstream I-yokes will be lowered along the material access shaft (trémie) and installed on air cushions at the bottom of the shaft.
- The corresponding I-yokes will arrive on a truck after which they will be rotated to their upright position on the parking area using the rental crane.
- The I-yokes are lowered along the shaft and installed directly onto their support.
- The final balancing of each yoke-element on its support is done with the help of mechanical jacks, so without the use of the crane.

- After the installation of all yoke elements, the full support moves to its final position using the air cushions.
- The air cushions are raised to allow the installation of the yoke supports on their rails, after which the air cushions are removed to allow their use for the installation of the next support element.
- The sequence is repeated until all yoke supports (I and C) are in their final position.

Fig. 14 represents two vertical cross sections of the cavern near the access shaft. It shows the position of the C-supports below the shaft during the above assembly procedure. A temporary protection will be mounted above the shaft during nights and weekends. The complete installation of the magnet yokes following the above sequence is estimated to last 3 weeks. This procedure allows avoiding the costly installation of permanent overhead cranes with a 60 t capacity both in the SX hall and in the cavern. Instead, permanent 10 t overhead cranes will be installed, which are powerful enough for the installation of the detector elements. The drawback of the above procedure is a loss of flexibility as well as the need for a perfectly flat cavern floor for the air cushion movements. Both the magnet supports and yokes are crude mechanical objects, which are not likely to need replacing during the duration of the experiment. Obviously, the reverse procedure has to be envisaged for the dismantling phase of the experiment.

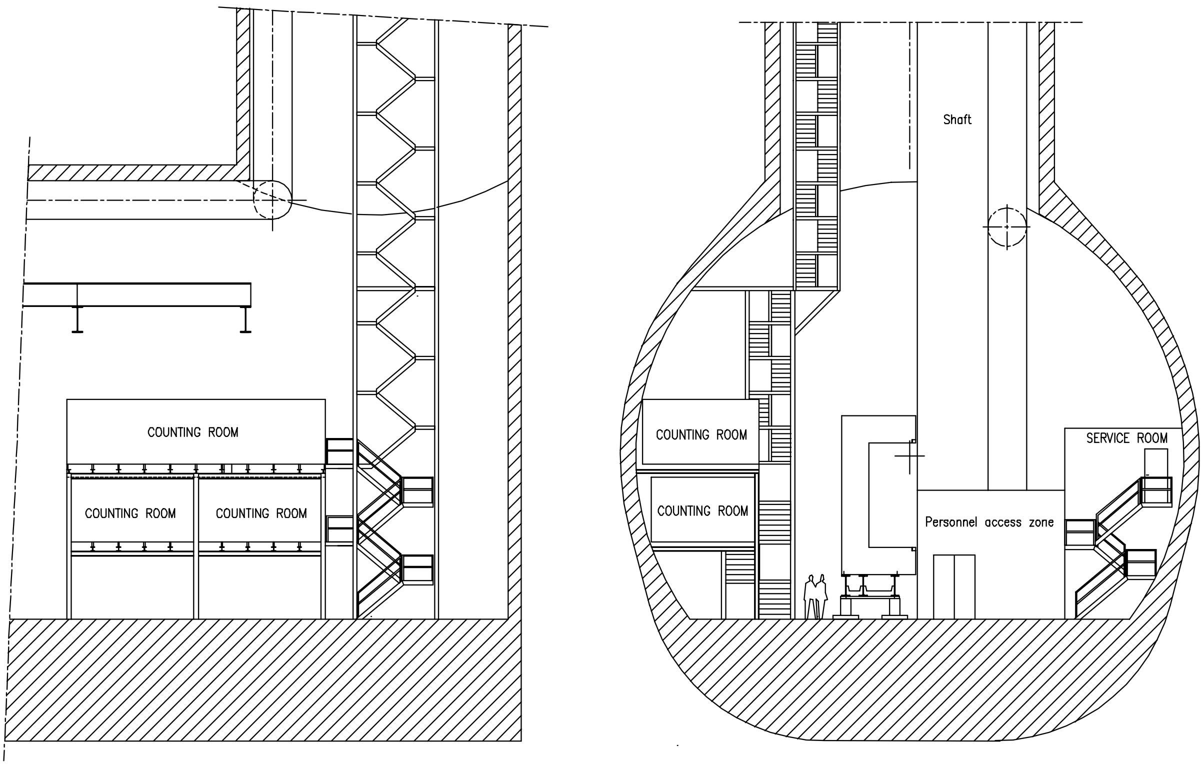


Figure 14: Vertical cross sections of the cavern and the shaft, showing the installation of the C-yokes at the bottom of the shaft. The service stairs of the shaft join the stairs giving access to the counting room.

The magnet coils and all other elements of the TOSCA detector will be handled using the permanent 10 t overhead cranes to be installed in the SX hall and in the cavern. The presence of the personal access shaft at the bottom of the cavern limits the movement range of the overhead crane along the beam axis. The crane cannot access the area below the material access shaft. Therefore all material will be lowered onto a trolley. The trolley will then move towards the manipulation surface upstream of the experiment, after which the equipment can be picked up by the overhead crane. The size of the manipulation area (10×10 m^2) is adapted to the size of the magnet coils and allows for the rotation, storage, assembly, small repairs and alignment of the detector elements (e.g. the muon chambers). The 3 m width of the material access shaft (trémie) is adapted to the installation of the C-yokes on their support (see Fig. 14). The 9 m length of the material access shaft is adapted to the length of the magnet yokes (including the handling frame).

The 10 t handling crane in the cavern has a lateral manipulation span of 10.5 m. This span is needed for the installation of the pairs of muon chambers. Given their 6 m height, they will pass along the side of the magnet, as they don’t fit over the top. The height below the crane hook amounts to 12.5 m. This dimension allows for 3.5 m high detector elements to be installed via the top of the magnet. The combination of the total height of the crane, the 50 cm safety distance above the crane imposed by safety rules, and the 17 m lateral floor dimension, fixes the 21.2 m cavern diameter.

The 10 t handling crane in the SX hall has a lateral manipulation span of 10.5 m. The height below the crane hook amounts to 6.5 m. This dimension is necessary for unloading the magnet coils and other detector elements from a truck. The overhead crane passes on top of the elevator shafts (see below). The cable lengths of 160 m allow for lowering equipment into the cavern. The total height of 11 m of the SX hall is determined by the height under the crane hook (6.5 m), by the size of the overhead crane, by a safety prescribed height above the crane support beams (2 m) and by the roof thickness.

5.2 Elevators

During the data taking periods of the experiment, no personnel will normally be present in the underground cavern, as the experiment will be fully controlled from the control room in the SCX building. However during the construction phase and at the occasion of technical interventions, it is expected that up to 20 persons will be present in the underground area.

The personnel access facility to the cavern is composed of a pressurised stair tower with two elevators. As the cavern is accessed by a single shaft only, a second elevator for personnel is prescribed by safety rules. One of the elevators gives direct access to the floor of the cavern. The bottom position of the second elevator is located at a height of 2 m above the cavern floor. This allows for evacuation of the personnel in the event of flooding. Otherwise both elevators are of the same type. Their weight capacity (1.6 t) and cabin floor dimensions (2.4×1.4 m^2) allow for the transportation of 21 persons, or for the evacuation of a stretcher. The door opening of 2.10×1.30 m^2 allows for the transportation of light materials (pallets, racks, the mobile pump of the fire brigade, etc). For safety reasons both elevators will be provided with an independent and uninterruptible power supply. To minimise the height of the surface hall, the machine rooms are located in the SX hall on the side of the elevators, rather than on the top. These machine rooms will be ventilated (air conditioning or open air ventilation).

6 Cooling and air conditioning

6.1 Primary cooling

Due to the proximity of residential areas and the airport runway, the use of standard evaporative cooling towers for the primary cooling appears impossible, because these devices produce high noise levels and steam plumes.

The alternative is therefore to transport the primary cooling from the nearest existing primary installation, LEP-PA8. For this purpose a trench of about 1.2 km length, 2 m depth and 2.5 m width is needed. The major part of the trench lies on Swiss territory. Therefore Geneva's "Services Industriels" (SIG), responsible for the supply of electricity and water in the canton, was consulted. The SIG firm determined the layout of the trench as depicted in Fig. 15. SIG will also cater for the drinking water and the drains of the experimental site. The existing primary installations (SF8) at LEP-PA8 will need minor upgrading to accommodate the demand of some 500 m^3/h (10 bar) for TOSCA. The main supply of electrical power and controls will also be conveyed along the trench from LEP-PA8, along with the computing networks, telephone cables and hard-wired alarms.

6.2 Secondary cooling

The cooling of the experimental magnet requires a cooling circuit with demineralised water with a flow rate of 200 m^3/hr. The air conditioning of the cavern, the counting room and the service room underground as well as the air conditioning of all surface buildings require a production plant of chilled water. The cooling of the electronics racks will make use of the chilled water circuit. A summary of the cooling power requirements and water flow capacities along with their characteristics is given in Table 4. It includes the cooling of the air handling units (AHU) for the air conditioning equipment (see section 6.3).

Circuit	**Power (kW)**	**Flowrate (m^3/hr)**	**Pressure (bar)**	**ΔT (°C)**	**Fluid**
Magnet	5500	200	25	26-52	Demineralised water
Primary of chillers	1000	15	5	26–31	Raw water
Ventilation AHUs	700	100	3	6-12	Chilled water
Fire fighting			14		
Seepage water (clear)		15	20		Infiltration
Waste water		3	20		Waste

Table 4: Summary of the cooling power requirements and water flow capacities.

Figure 15: Aerial view of the LEP-PA8 and TOSCA sites including the layout of the trench connecting the two sites.

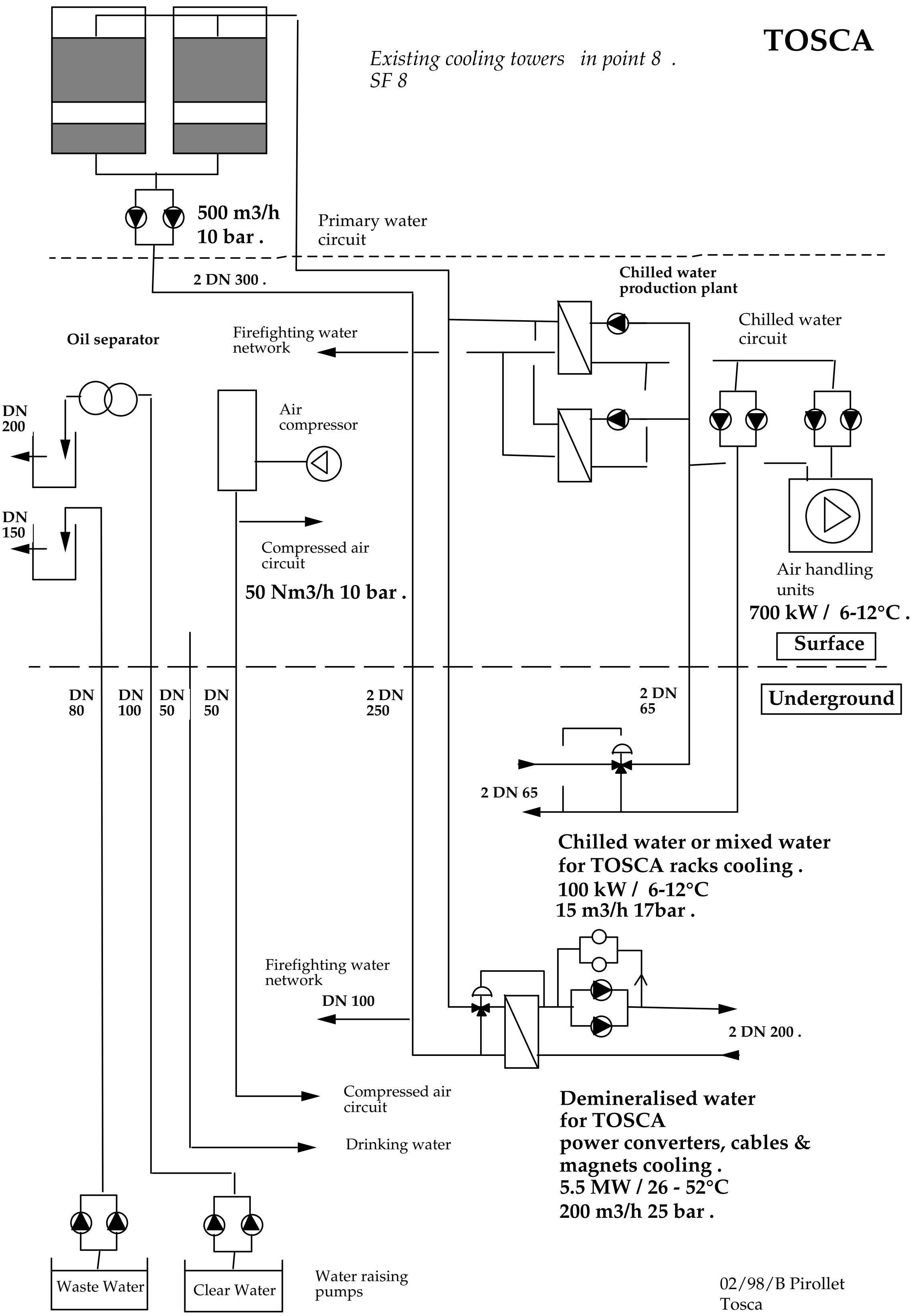


Figure 16: Schematic layout of the cooling systems and water circuits.

The schematic layout of the cooling and water circuits is depicted in Fig. 16. The main elements are:

- The demineralised water circuit for the magnet. It is directly connected to the primary water supply and will be housed in the service room down in the cavern. The station will consist of a heat exchanger, filter, two pumps (200 m^3/h, 25 bar), power and control cabinets and the distribution piping for the magnet cooling and its associated water-cooled cables.

- The chilled water production plant. This plant will consist of two liquid chillers of the hermetic screw compressor type, producing chilled water at 6ºC. They have a specific capacity of 500 kW each and will be housed on the bottom floor of the SUX building (see Fig. 13 of Appendix A). The chilled water will be distributed by two different sets of pumps. It will be pumped to the AHU's in the ventilation room, for the needs of the air conditioning, and to the underground cavern, for the cooling of the electronic racks. Each distribution circuit will feature two pumps (one on stand-by) for improved reliability.

- The fire fighting circuit. It will be connected to the primary water piping (from SF8). The fact that the cavern will be 150 m underground will provide a static pressure of 15 bar, eliminating the need for an uninterruptible power supply. Hose connections will be provided every 50 m along the shaft and at the entrance to the cavern.

- Drinking water. It will be supplied from the standard SIG network and will be provided to the control room and to the toilets both in the SCX surface building and in the cavern.

- Seepage water. It will be collected from the cavern and pumped to the surface, where it will go through an oil separator and checked for contamination prior to being discharged to the local waste collector.

In addition, an air compressor (50 Nm^3/h, 10 bar) will be installed in the SUX building to supply compressed air in the SCX workshop and in the cavern (power tools and cleaning).

In case of flooding, the seepage water discharge line along the shaft can be used as a wet standpipe for the evacuation of water from the cavern.

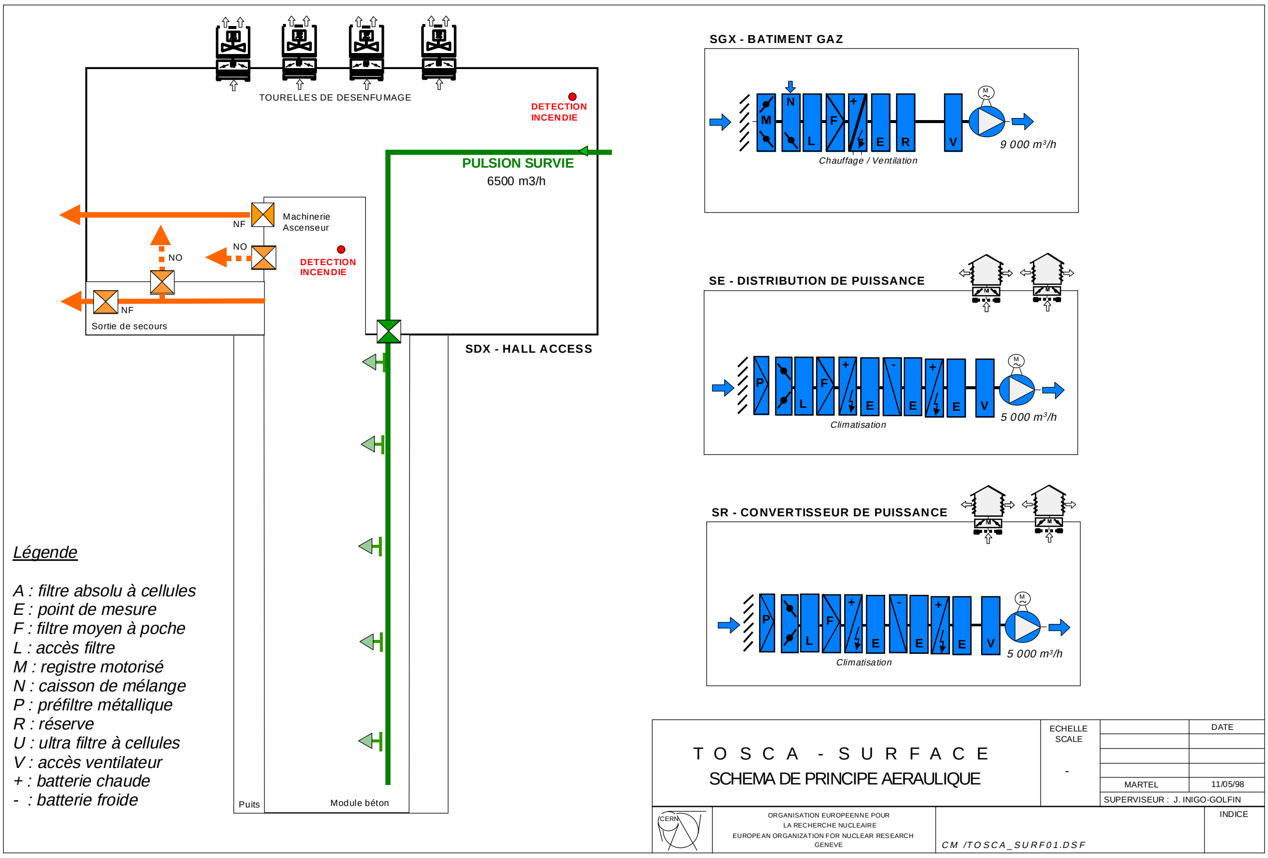
6.3 Air conditioning

Most of the air conditioning equipment will be housed on the ground floor and first floor of the SUX building (see Fig. 13 of Appendix A). Table 5 shows a summary of all air conditioning requirements along with their main characteristics. All systems are of the standard type installed at CERN. The air is filtered, treated (dehydrated and cooled), reheated if necessary and supplied to the conditioned spaces by means of ducts. An all fresh-air principle has been adopted, imposed by the fact that the cavern can be accessed at any time. Separate units extract the air from the conditioned spaces. The latter also serve as smoke removal systems in case of an emergency. A schematic of the air conditioning installations is shown in Fig. 17.

Surface buildings				
CIRCUIT	Winter/Summer Temperature (ºC)	Winter/Summer Dew-point (ºC)	Flow rate (m^3/h)	Remarks
Heating and ventilation of surface hall SX	19±2	Max. 15	20 000	
Smoke removal of surface hall SX			60 000	UPS (Safety element)
Heating and ventilation of ventilation room SUX	19±2	Max. 15	20 000	
Smoke removal of ventilation room SUX			20 000	UPS (Safety element)
Air conditioning of building SCX	26±1	= 12	5 000	
Air conditioning of converter room SR	26±1		5 000	
Heating and ventilation of power distribution room SE	19±2	Max. 15	5 000	
Heating and ventilation of gas mixing building SGX	20 to 22		9 000	

Underground cavern				
CIRCUIT	Winter/Summer Temperature (ºC)	Winter/Summer Dew-point (ºC)	Flow rate (m^3/h)	Remarks
Pressurisation of lifts and emergency stair-tower	22	EJP= outside	8 000	UPS (Safety element)
Air conditioning of the cavern – supply	22 to 26	= 12	30 000/ 60 000	
Air conditioning of the cavern – exhaust			30 000/ 60 000	
Gas extraction			5 000	UPS (Safety element)
Smoke removal cavern			60 000	UPS (Safety element)
Toilet extraction			300	
Air conditioning of racks	22 to 26	= 12	5 000	
Coolbox	5± 0.5	= -10	1 000	UPS (Safety element)

Table 5: Summary of the air conditioning elements; UPS stands for uninterruptible power supply



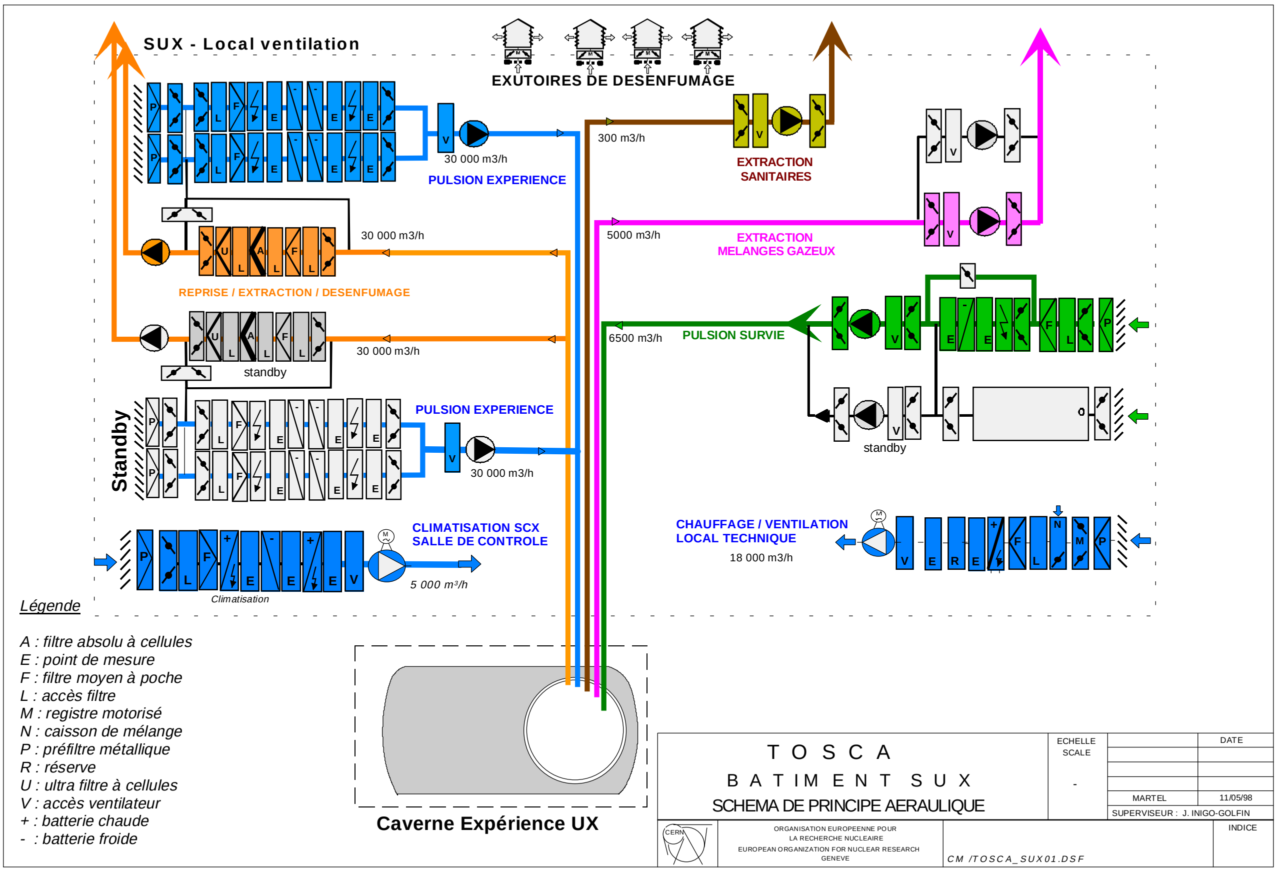


Figure 17: Schematic of the air conditioning installations.

Those items that are considered as safety critical have a high redundancy and are provided with uninterruptible power supplies (UPS):

- the smoke-removal units. They can be operated by the fire brigade only and can either be used as a smoke management system (to improve or maintain visibility in case of fire during the evacuation and extinction phases) or to remove the smoke after the fire has been extinguished. These units need to be operated together with the air supply fans.
- the gas extraction system. It is intended as a permanent venting of the gas-air mixture, which might exist near the detectors, to avoid the presence of high concentrations of toxic or flammable gases in the cavern.
- the pressurisation of the emergency stair-tower and the elevators.
- the smoke extraction in the surface buildings. It is performed by a series of roof-top extraction fans.

The air conditioning of the coolbox shows certain peculiarities with respect to the rest of the systems described so far. The need of a constant and very reliable control of the level of humidity inside the coolbox suggest the use of a chemical dehydration system, combined with a steam injection device to compensate for the low level of humidity during the winter season as well as during dry summer periods. Due to the very long periods of time during which the emulsions remain inside the coolbox, an extremely reliable system is needed to prevent damage to the emulsion in case of a general power failure. For the same reason, all the air conditioning system components have a high redundancy.

6.4 Contingencies

One should consider the possibility of encountering hydrocarbons in the water tables surrounding the cavern. The experience in LEP-PA8 is that quantities of oil mixed with water infiltrate through the walls of the cavern. This water has to be collected at the drains and pumped to the surface, where it is treated.

Without the necessary sampling it is impossible to predict at this time, whether such a problem also exists at the site chosen for TOSCA, but in view of the proximity to LEP-PA8, this is very likely to be the case. Therefore a specific budgetary provision has been included in the cost estimation (Appendix B).

7 Electrical power distribution

A summary of all electrical power needs is given in Table 6. The total requirements amount to 8581 kW, of which 585 kW is to be assured with uninterruptible power supplies. Like for the primary cooling water and other service supplies, the electrical power will be provided from LEP-PA8. An 18 kV link will be included in the 1.2 km long surface trench. The 18 kV substation on the SBL site will be equipped with a complete set of auxiliaries and safety systems. It will be placed in the SE building.

The 400 V power distribution on the surface and in the cavern will comply with the same standards as on the LEP sites. This will also be valid for all auxiliary and safety systems. Most surface buildings will have individual switchboards placed on false floor areas. A few smaller buildings will contain secondary switchboards only. In the cavern, both a normal supply and a safe supply switchboard are foreseen. The safe supply switchboard will be installed in the safe room, which is part of the service room. The safe room, composed of a fireproof concrete enclosure, will house all equipment linked to safety.

For the current cables to the magnet, 8 cm diameter water cooled busbars transporting 2500 A each were chosen.

A safe power source will be required to fulfil the INB requirements for safe power for lifts, ventilation, smoke extraction, anti-panic lighting and other critical installations. Given the power requirements and the distance from other installations, a diesel-powered generator is most appropriate. This generator will start automatically and supply the safe supply switchboards. Vapour lamps are foreseen for the lighting in the halls. The SCX control room building, and the other lower surface buildings will be fitted with light fittings for fluorescent tubes.

Electrical Power Requirements					
				Power (kW)	Comment
Cooling				**747**	
	Demin. water for magnet (180 m^3/h magnet, 20 m^3/h water-cooled cables)	200 m^3/h	25 bar	170	
	Cavern seepage pumps	15 m^3/h	20 bar	15	UPS
	Toilet pumps	3 m^3/h	20 bar	5	
	Compressed air	50 Nm^3/h	10 bar	50	
	Water chillers 2×500 kW			300	
	Chilled water pumps for air conditioning	100 m^3/h	3 bar	15	
	Chilled water pumps for water cooled racks	15 m^3/h	17 bar	9	

	Chilled water pumps (circulation pumps)	115 m^3/h	3 bar	13	
	SF8 primary pumps	500 m^3/h	10 bar	170	SF8
Lifts and Cranes				**128**	
	Personnel lift 1			50	UPS
	Personnel lift 2			50	UPS
	Surface crane	10 t		14	
	Cavern crane	10 t		14	
Ventilation				**1920**	
	Cavern supply			1250	50 kW UPS
	Cavern extraction			50	UPS
	Gas extraction			15	UPS
	SUX smoke extraction			20	UPS
	Surface hall smoke extraction			20	UPS
	HV ventilation room			275	
	Toilet extraction			5	
	Shaft safety overpressure			135	UPS
	Coolbox			150	UPS
Fire Detection				**21**	
	Cavern and shaft detection			7	
	Oxygen detection			7	
	Cavern gas detection			7	
Access Control				**10**	UPS
Gas Mixing				**20**	UPS
Lighting				**60**	
Experiment				**5675**	
	Racks			125	
	Magnet			5550	
Total Power				**8581 kW** (UPS **585 kW**)	

Table 6: Electrical power requirements

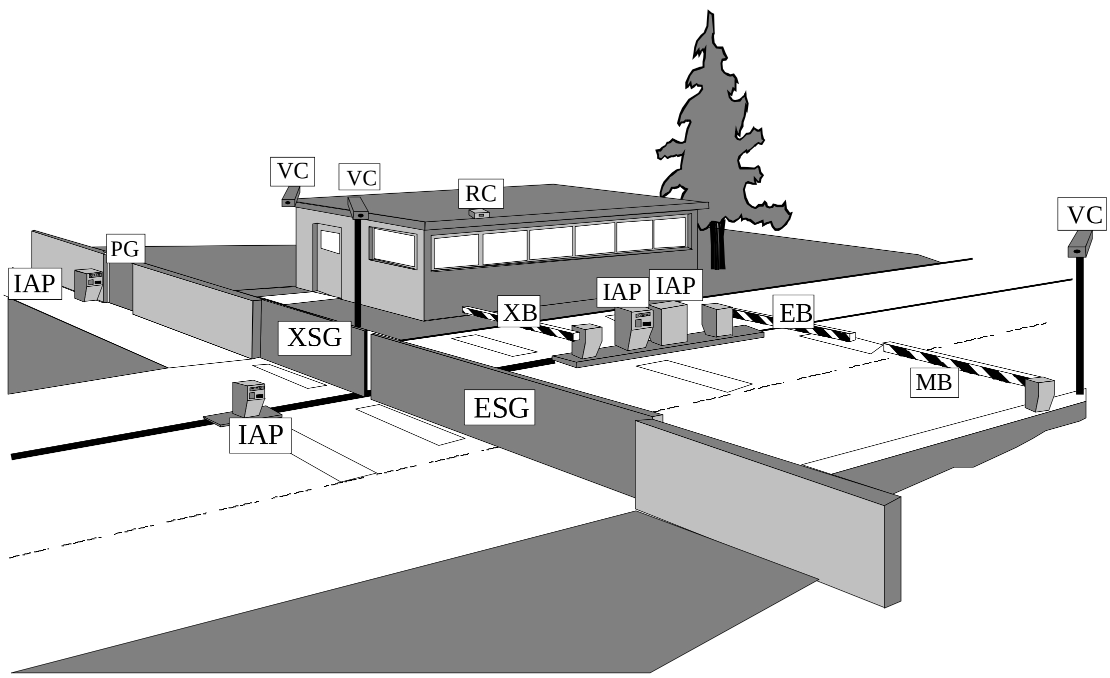
8 The access control system

8.1 General considerations

The design of the SBL site includes an Access Control System providing protection of personnel and equipment. As the project infrastructure will be located on a new CERN site a “Road Access Unit” is foreseen, assuring the site’s privacy. Access to the experimental cavern will be possible via 2 lifts and staircases located in the SX hall. Safety rules limit the access to the cavern to the personnel capacity of the elevators. Therefore a specific “Building Access Unit” is to be provided. As the neutrino beam does not give rise to any level of radiation, there is no need for a machine interlock system. Therefore no controlled access equipment is foreseen in the underground area.

8.2 Site access control systems

The foreseen “Road Access Unit” is similar to the existing SPS units. It will be set up at the entrance to the TOSCA site and used to control traffic and pedestrian access. It will consist of the equipment shown in Fig. 18.

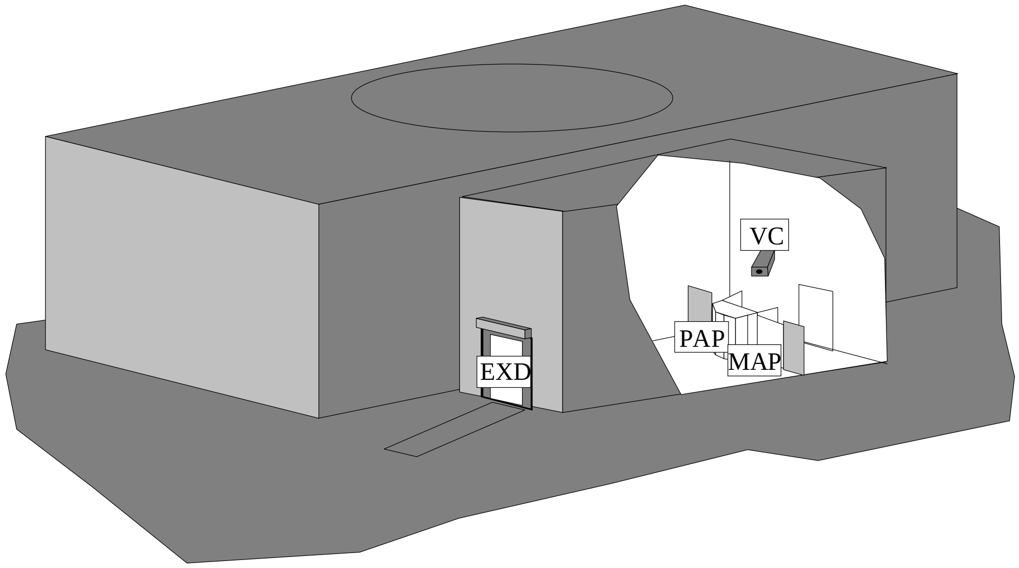


XB : Automatic eXit Barrier
EB : Automatic Entry Barrier
IAP : Identification Access Point
ESG : Entry Sliding Gate
XSG : eXit Sliding Gate

VC : Video Camera
RC : Radio Command
MB : Manual Barrier
PG : Pedestrian Gate

Figure 18: The “Road Access Unit” with its functional elements.

The “Building Access Unit” will be used for personnel and material access control to the cavern and will consist of the equipment shown in Fig. 19.



PAP : "Personnel" Access Point (turnstile or "sas")
MAP : "Material" Access Point (Motorized Door)
(Controlled and Commanded)
EXD : Emergency eXit Door
(only Controlled)
VC : Video Camera

Figure 19: The “Building Access Unit” with its functional elements.

All units described may be controlled either locally (through the local control room), and/or centrally, through the CSA (Centrale de Surveillance des Accès). The access control systems will be integrated into the existing access control philosophy.

9 Fire detection and gas detection

9.1 Underground area

For the fire detection system infrared optical beams, smoke sampling pipes and, possibly, some point detectors will be used. These systems have the advantage of being both reliable and economical to implement. The optical beams will be used to monitor the whole cavern. They will be fixed at a height that is low enough to ensure that the smoke generated by a fire is not too diluted before interacting with the beams. The height, however, will have to be compatible with the crane movements. If necessary, several beams can be coupled to avoid false alarms.

Inside the counting room and service room air sampling systems are foreseen to monitor the installations present there.

9.2 Surface buildings

Large surface buildings will be monitored by optical beams. Here again, attention will be given to the presence of cranes. The beams will be located high enough to avoid interference with moving objects or people, since this will cause false alarms. Smoke detectors will also be located near electronics racks in the various buildings.

9.3 Oxygen level monitoring

An oxygen level monitoring system will be installed in the cavern. This system will be connected to the level 3 alarm system.

9.4 Alarm transmission

As the TOSCA site will be outside the CERN perimeter, a custom alarm transmission system will be installed. Since fire alarms are level 3 alarms (generated when life might be in danger), they have to be transmitted by two different methods, thus ensuring both redundancy and diversity of the safety system. One way may be to use the computer network that will be installed for the experiment in any case. The second way will consist of a hard-wired synoptic panel with hard-wired connections to the SCR (Security Control Room) of the CERN Fire Brigade. Cabling for each of these transmission systems should be following a different route.

9.5 Gas detection

As described in section 10, the TOSCA experiment will use various types of gaseous tracking detectors. For safety reasons, none of the gases considered will use flammable components in concentrations above the lower flammable limit. Therefore gas detection will only be installed in the SGX surface building. Gas alarms will be transmitted automatically to the TCR (Technical Control Room) and to the SCR of the CERN Fire Brigade.

10 Detector gas distribution

The TOSCA experiment will use several types of gaseous tracking detectors, both for tracking inside the spectrometer magnet and for muon detection. These detectors will need permanent circulation of different gas mixtures. Therefore the necessary infrastructure will be included at the SBL site. At the present stage, final choices of detection technologies have not been made. The technology options include Time Projection Chambers (TPC), Resistive Plate Chambers (RPC) and various types of Drift Chambers. For the study of the required infrastructure, assumptions were made for the potential types of gas and their average flow rate. These assumptions are based on the present detector options. For safety reasons, none of the options considered at present will use flammable gases in concentrations above the lower flammable limit. The assumed gas types and flow rates are summarised in Table 7.

Item number	**Gas type**	**Flow rate (m^3/day)**
1	Argon	80
2	Nitrogen	10
3	CO_2	30
4	Methane CH_4	2
5	Isobutane (iCH_4H_{10})	0.5

Table 7: Assumed gas types and flow rates.

The basic infrastructure at the SBL site is drawn schematically in Fig. 20. It will comprise:

- Gas mixing and circulation systems (items 1 and 2). Such systems are very specific to the choice of the detector technology and are considered as part of the experimental equipment. In the present design and cost estimate the basic infrastructure to receive this equipment (SGX gas building and piping) has been included.
- Principal gas supplies through dewars (items 3 and 4), including piping. Rental dewars have been assumed.
- Principal gas supplies using gas cylinders and semi-automatic switch-over systems (items 5, 6, 7), including piping.
- Storage of gas cylinders.
- The piping through which the detector gas mixtures are taken from the SGX surface building to the experimental cavern and vice-versa. Welded stainless steel piping is foreseen. The welds will be verified using X-ray methods.
- Compressor systems in the cavern (items 8 and 9). Again, these systems are specific to the detector options, therefore only the piping was included in the present study.

The main components of the detector gas infrastructure are foreseen in a single surface building (SGX). The building will comprise a closed part, where the gas mixing and circulation systems will be housed. At the front part of the building there will be a surface protected by a roof, under which the gas cylinder supplies are placed. The isobutane supply will be housed in a commercial shell-structure, which comprises a heating system to maintain a stable vapour pressure.

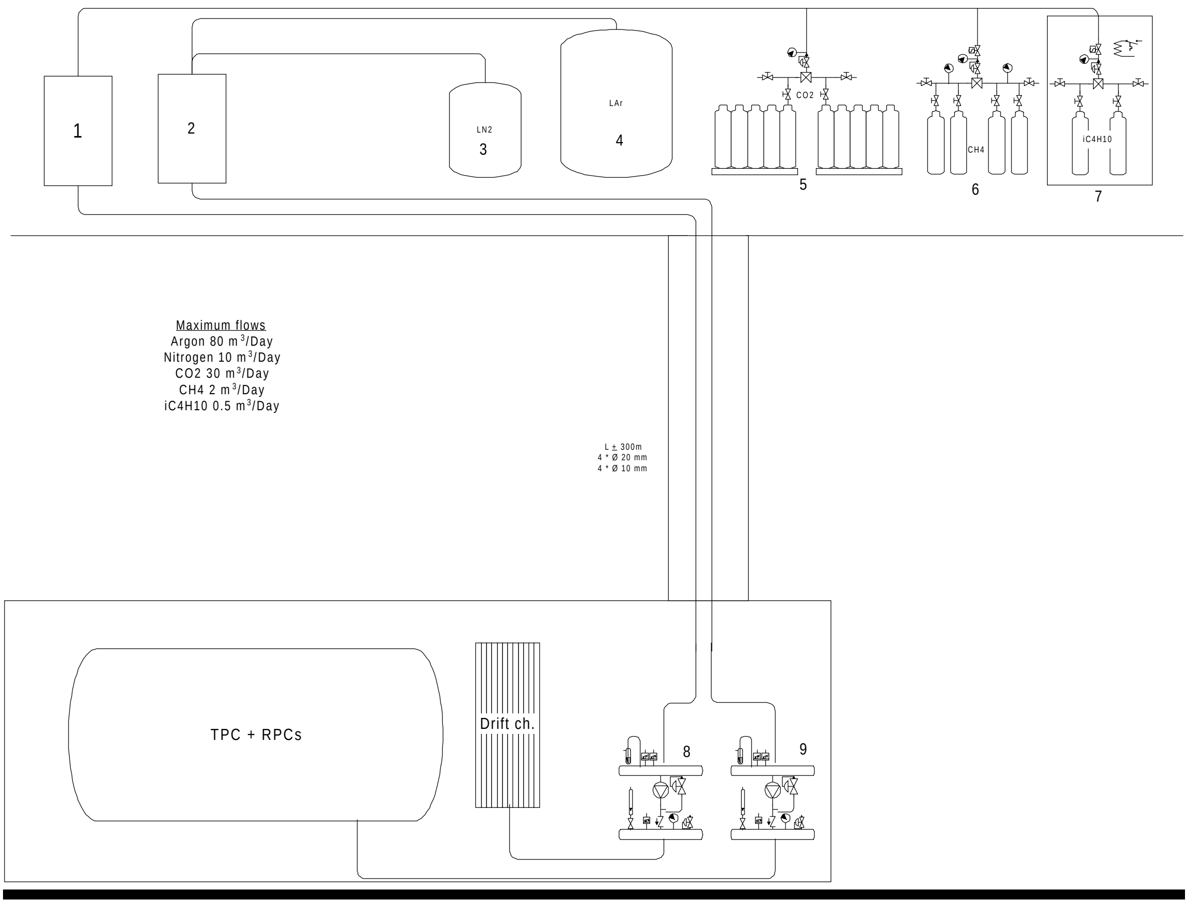


Figure 20: Schematic of the detector gas supplies comprising the following elements: mixer, circulator and purifier systems for two different mixtures (1,2); a 200 l mobile liquid Nitrogen evaporator (3); a 2000 l liquid Argon evaporator (4); two CO_2 batteries with a semi-automatic inverter (5); four CH_4 bottles with a semi-automatic inverter and safety valve (6); two iC_4H_{10} bottles with a semi-automatic inverter and safety valve (7); a compressor unit for the TPC detector (8); a compressor unit for the drift chambers (9).

11 Conclusions

A design study was done of a "Near Detector Site" for a Short Baseline neutrino oscillation experiment on the recently designed CERN neutrino beam to the Gran Sasso laboratory in Italy. The site is located at 1858 m from the neutrino target and 151 m underground. The present study includes a civil engineering design, safety aspects, heavy handling, cooling, ventilation, electricity, access control, fire detection, gas detection, detector gas supplies and computer links. It also includes a proposal to transport various supplies like cooling water, electrical power and computer links from an existing CERN site. The study was adapted to the size and infrastructure demands of the intended TOSCA experiment. However, many of the details are applicable to any alternative experiment at the "Near Site".

Acknowledgements

The contributions of many people have allowed for the fast completion of the present design study. The efficient touch of J. Barney to the editing of the document was of invaluable help. P. Dacher and L.A. Lopez-Hernandez participated in the initial stage of the project. G. Gallay, H.D. Graskamp and O. Böhner were frequently consulted on details of the magnet. A. Feron, M. Guerrero, L. Henny, R. Parker, A. Vital and O. van der Vossen have fruitfully contributed to the information compiled in the report.

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Appendix A Civil engineering figures

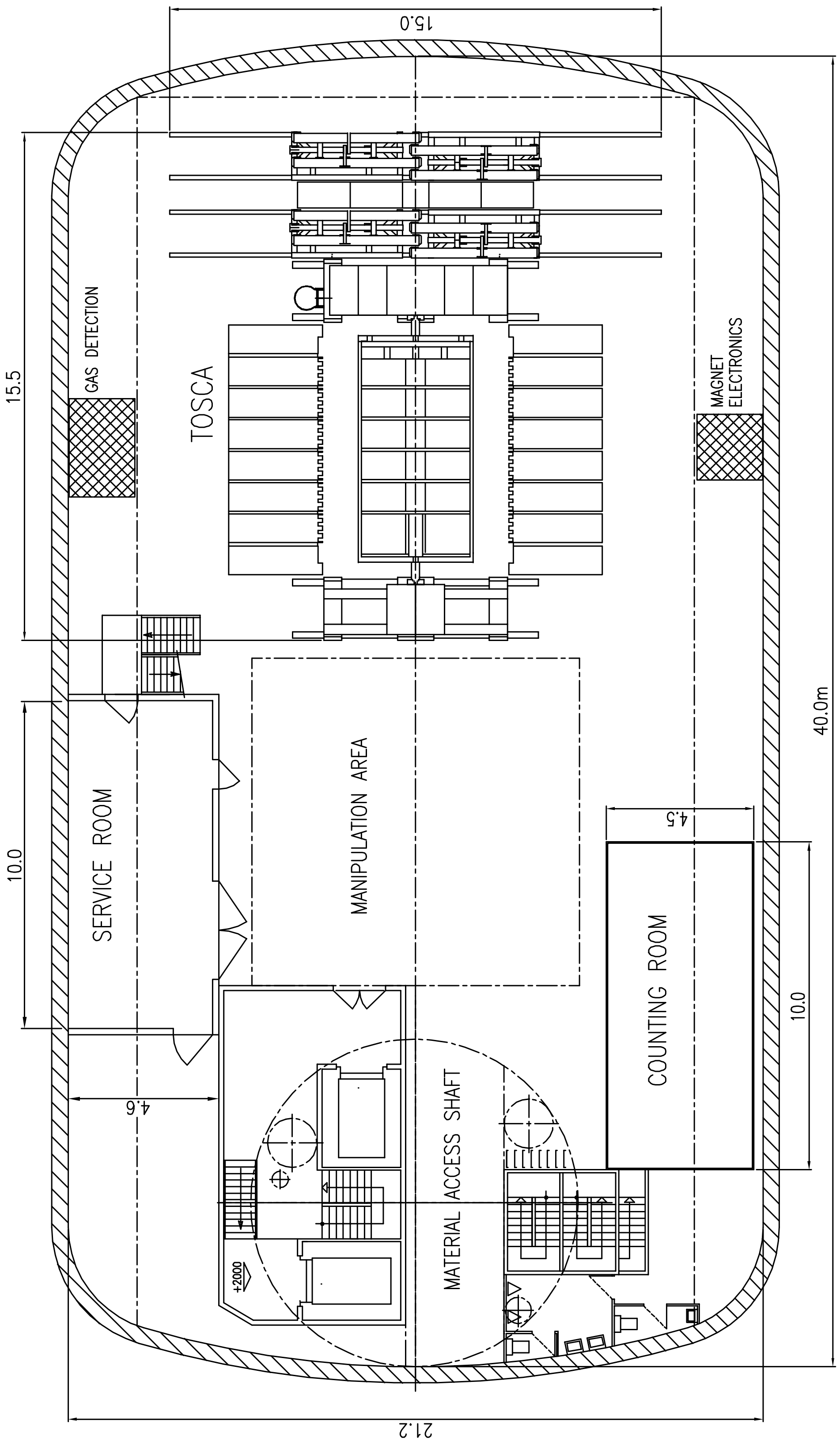


Figure 6: Top view of the experimental cavern.

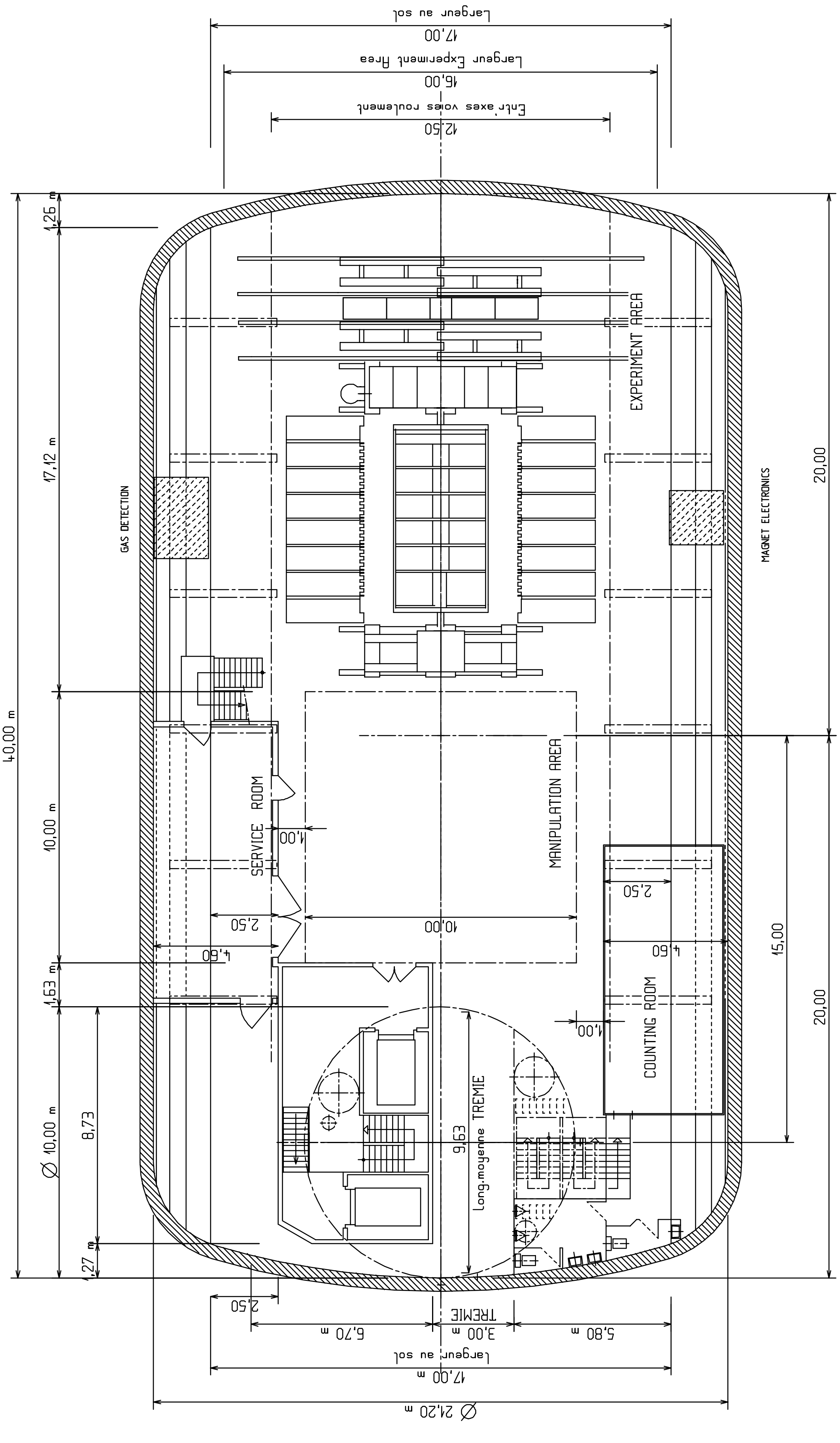


Figure 7: Top view of the experimental cavern indicating various dimensions.

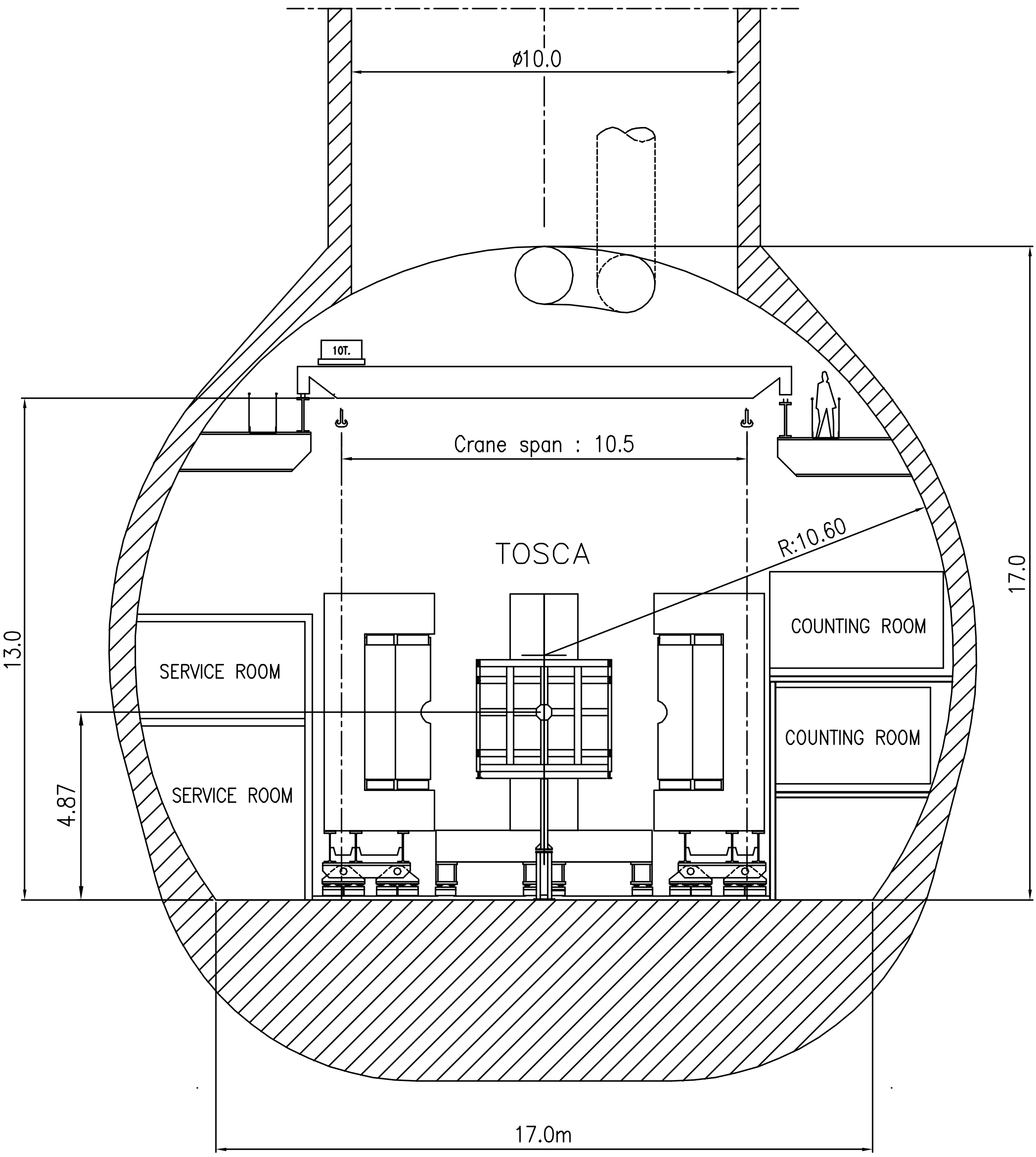


Figure 8: Vertical cross section of the experimental cavern at the position of the TOSCA magnet.

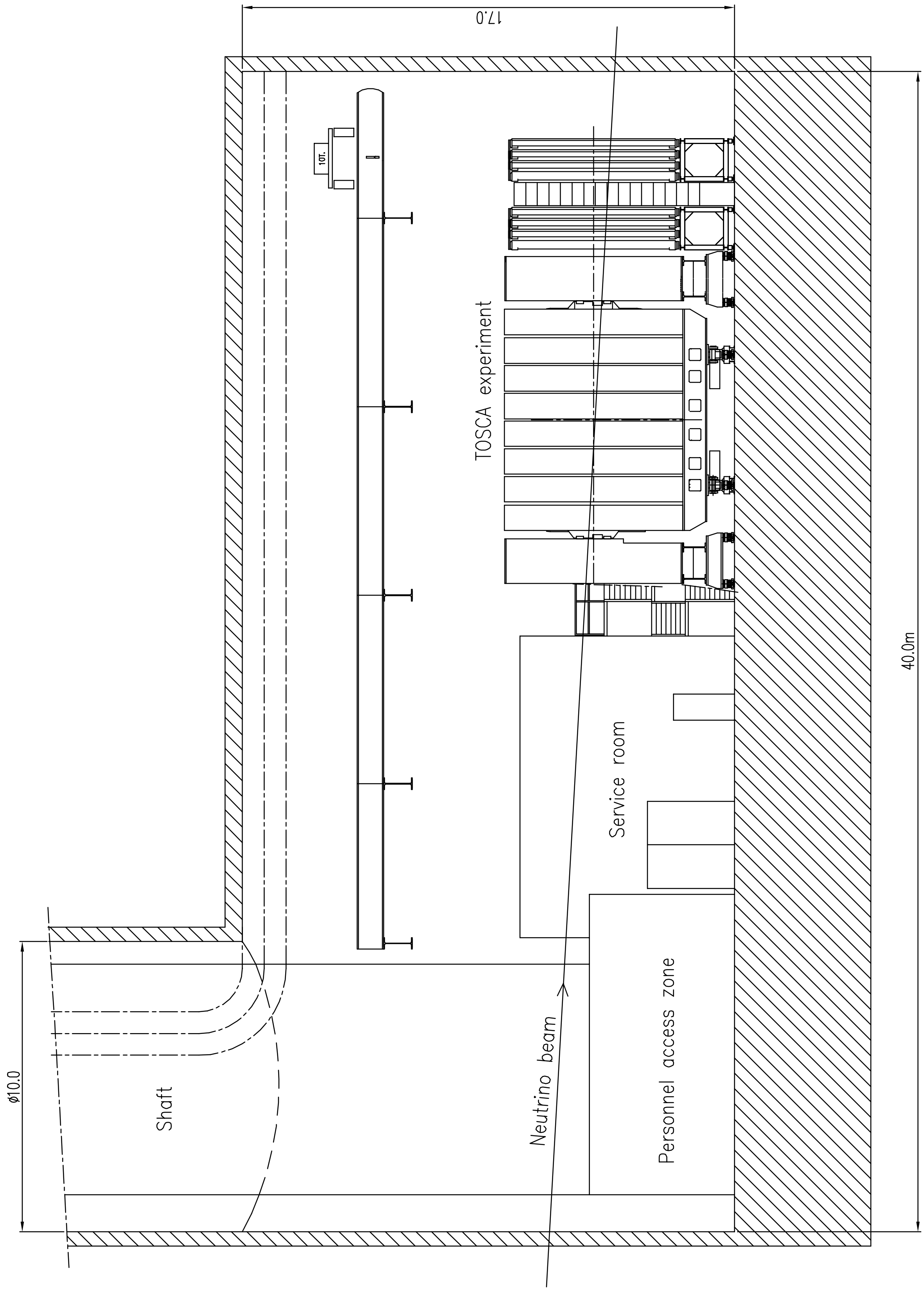


Figure 9: Longitudinal cross section of the experimental cavern.

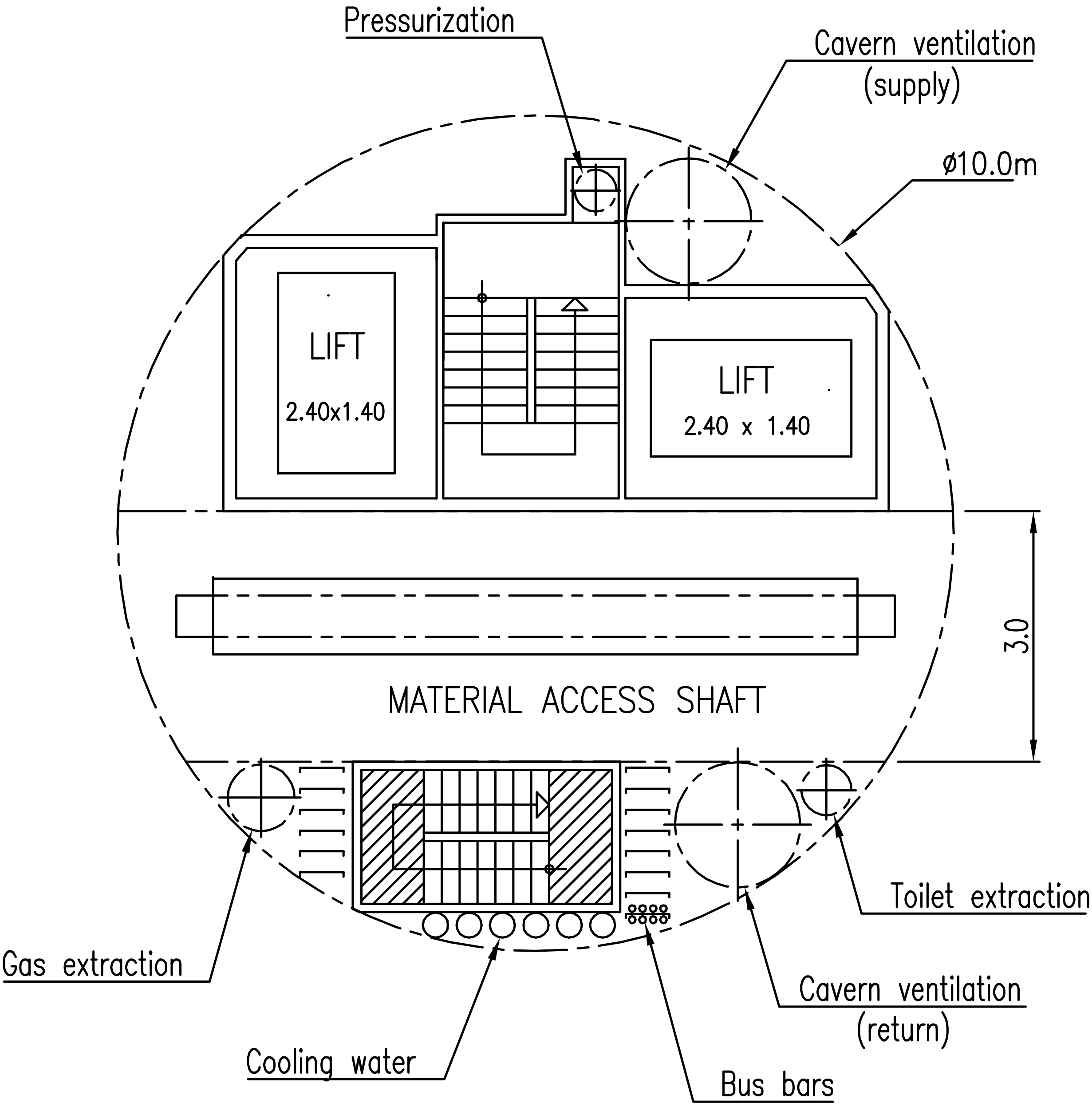


Figure 10: Cross section of the access shaft.

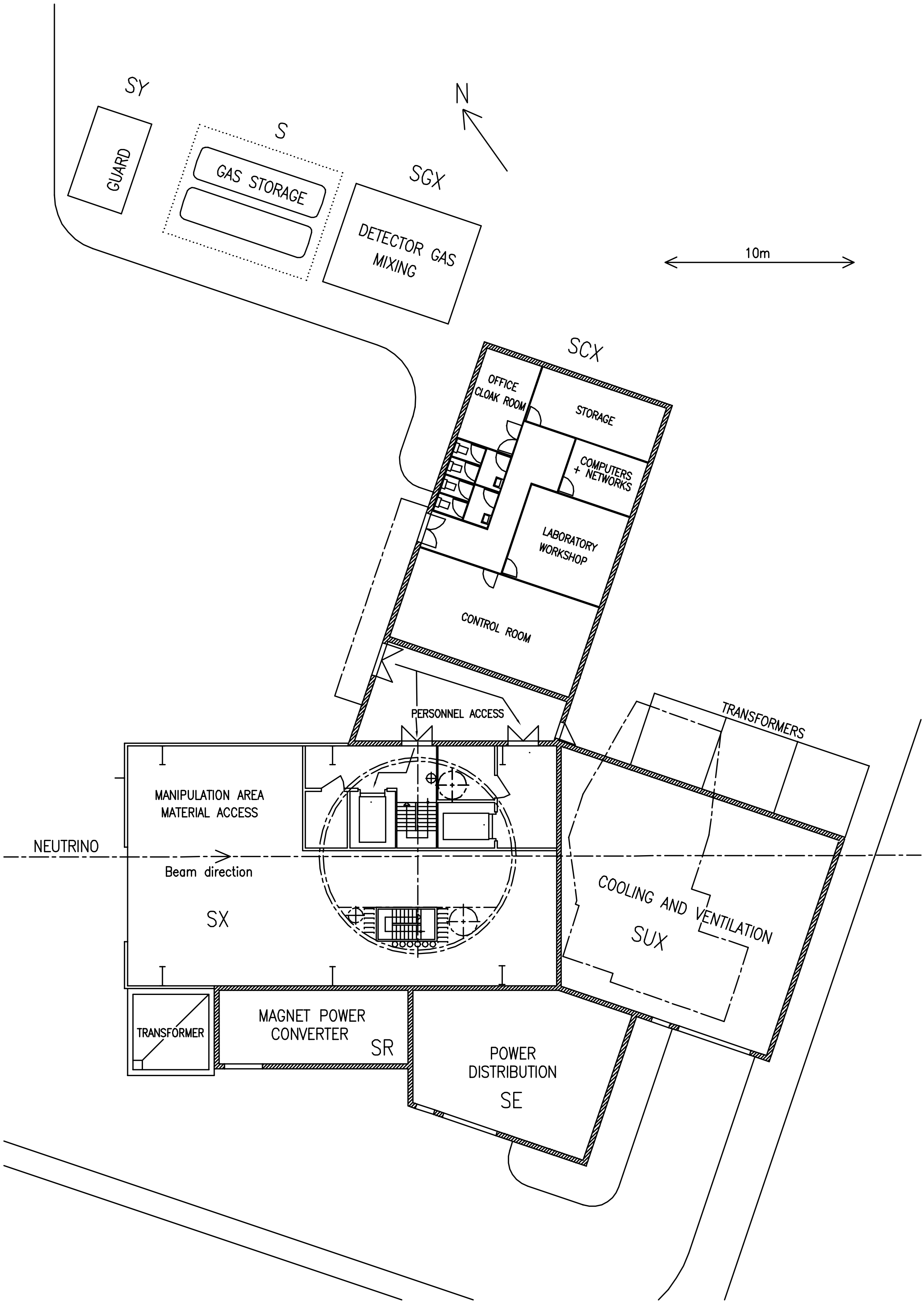


Figure 11: Layout of the surface buildings.

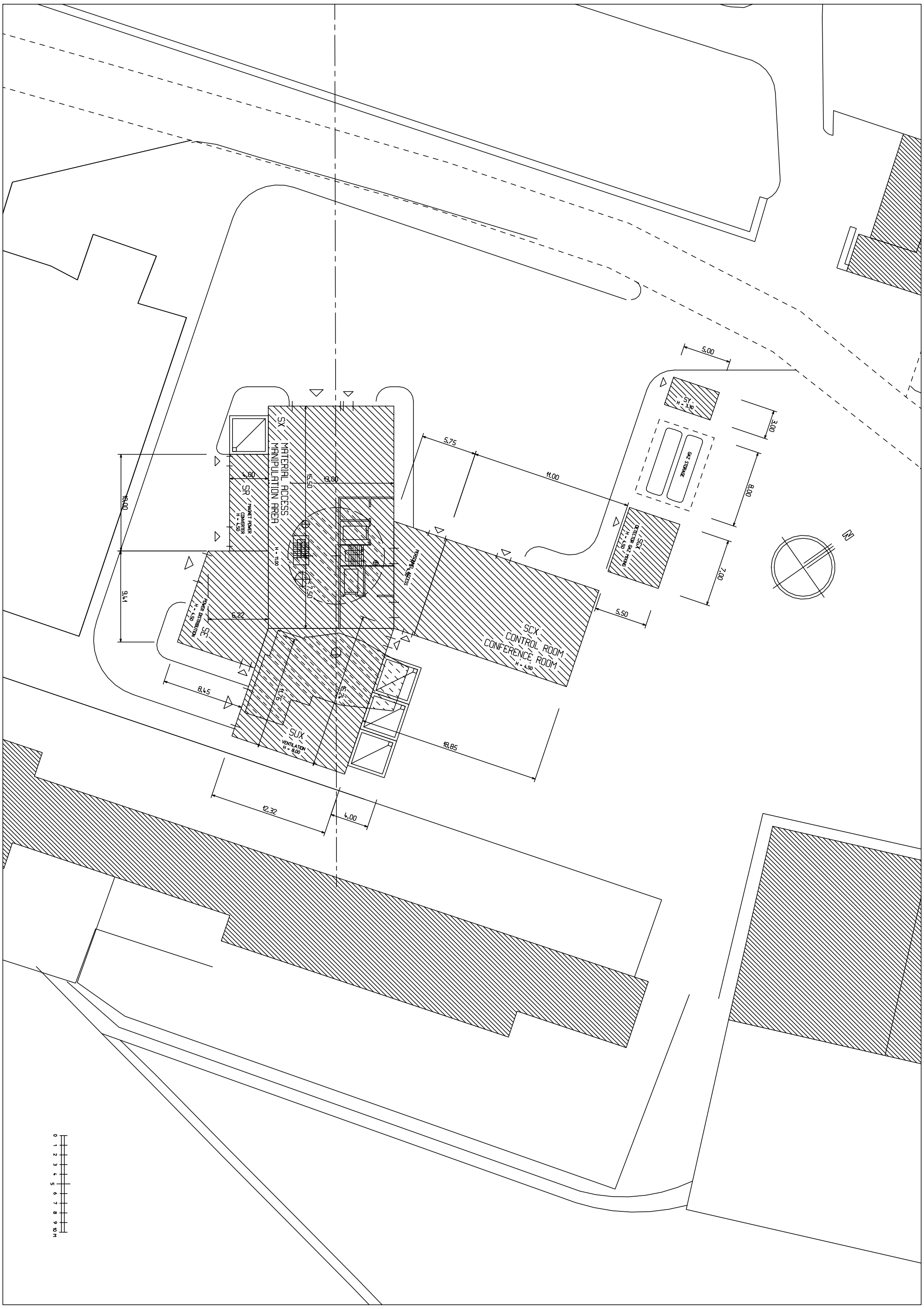
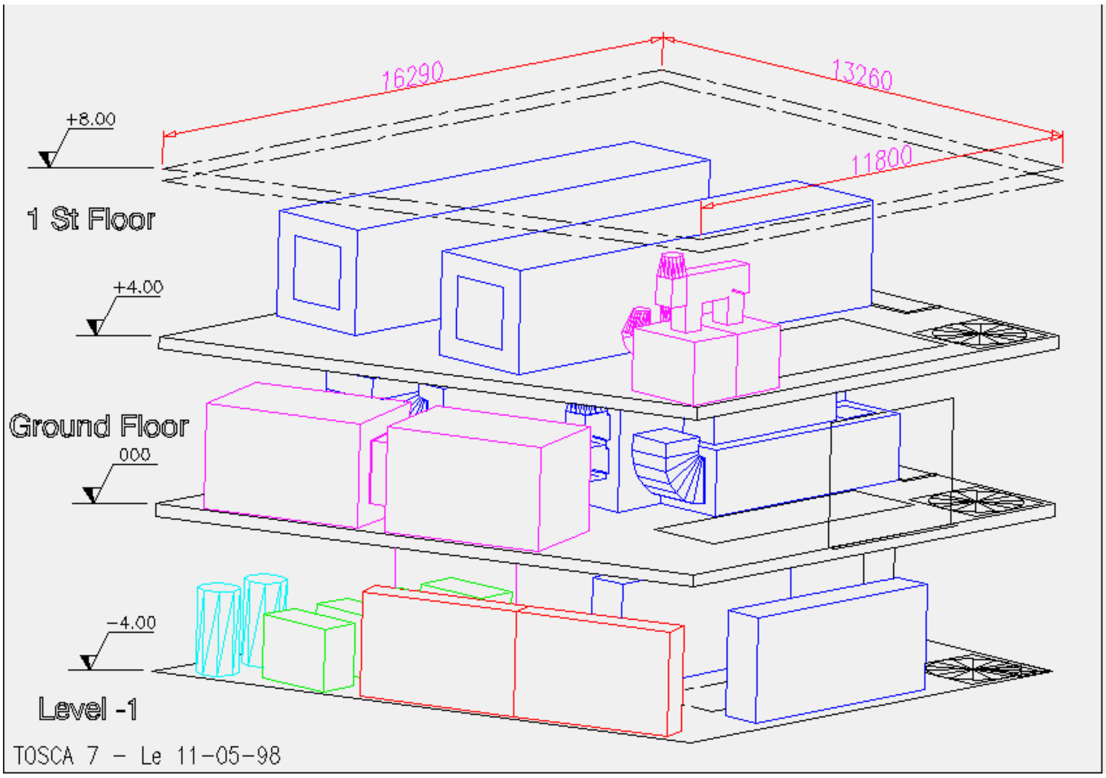


Figure 12: Layout of the surface buildings, showing their position with respect to the existing buildings and the road (dashed).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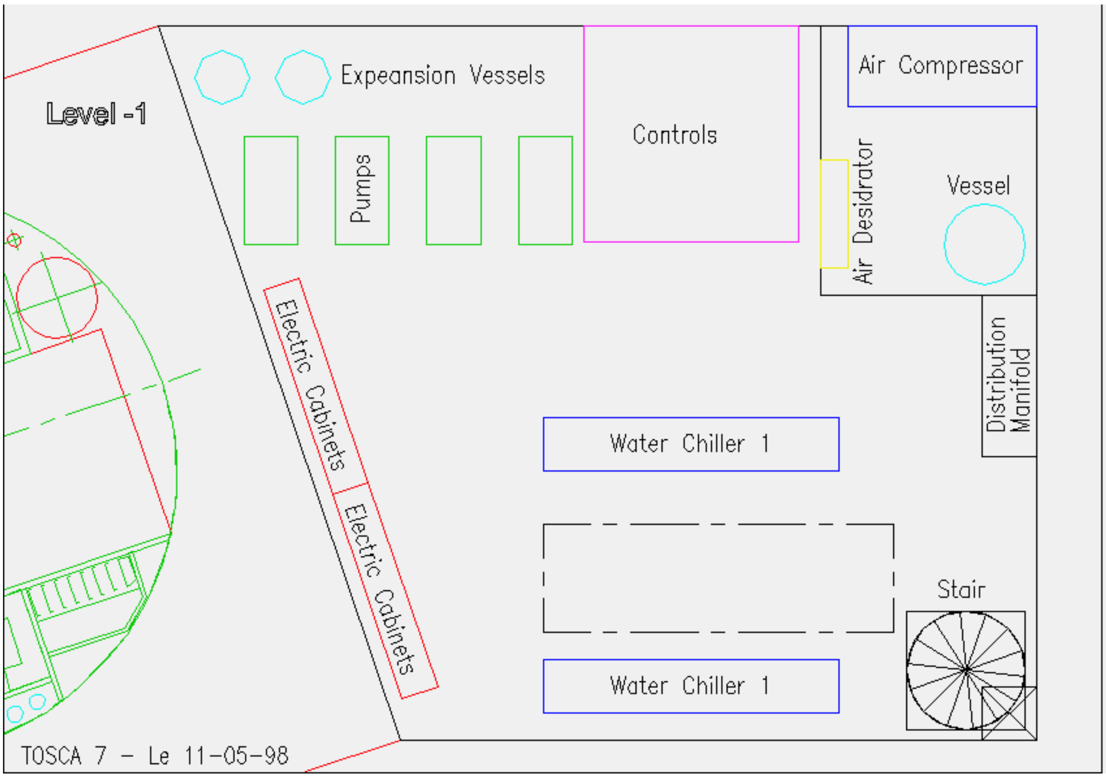
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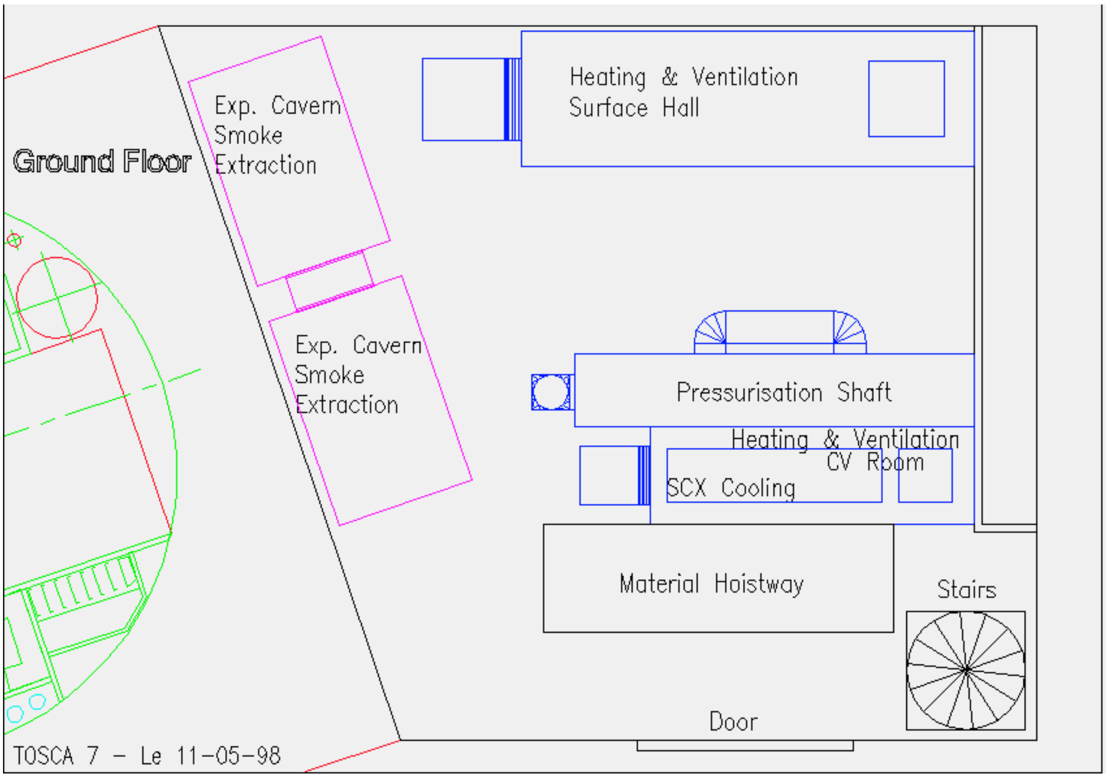

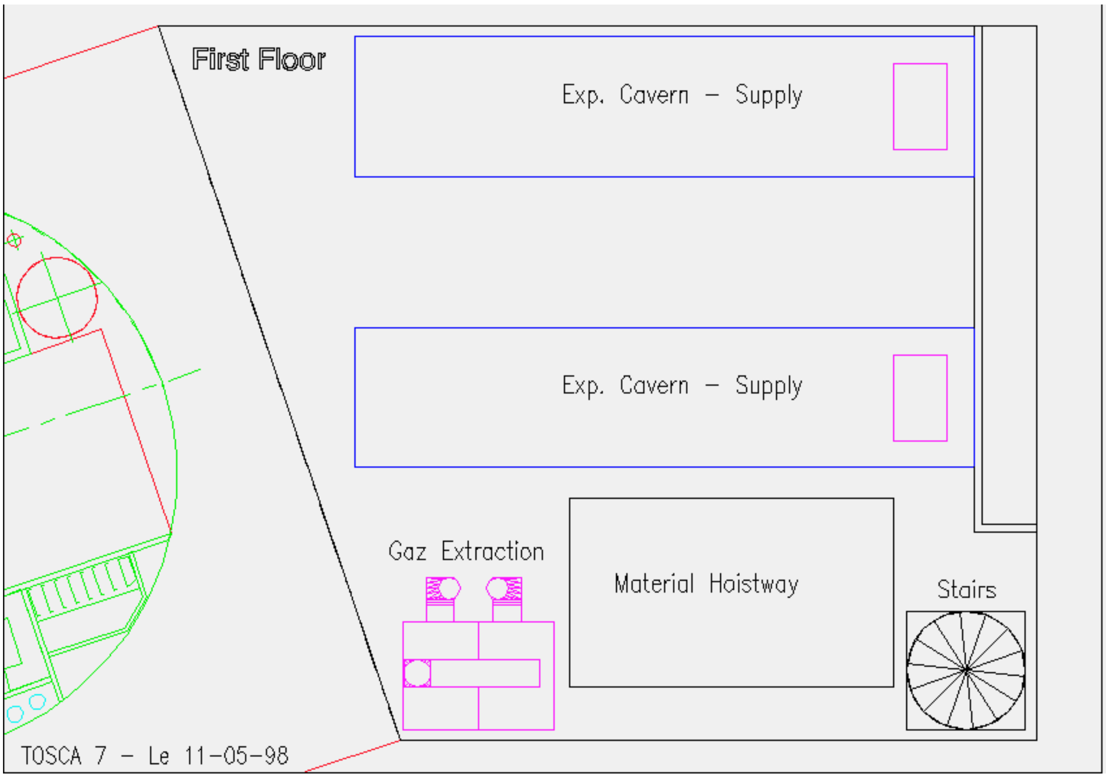

Figure 13: Layout of the SUX building and installation of the cooling and air conditioning equipment on the three floors of the SUX building.

Appendix B Cost Estimates

Item	Cost (kSF)
Civil Engineering	23032
Lifts & Cranes	4335
Cooling	4420
Ventilation	5165
Electricity	2820
Access Control	350
Fire Detection	648
Gas Detection	55
Telecommunications	70
Computer networks	150
Detector gas supply	150
Contingencies (oil separator)	250
Total	**41445 kSF**