CHAPTER 10

EXPERIMENTAL AREAS

10.1 INTRODUCTION

As already described the initial experimental programme at the LHC consists of five experiments installed in four experimental areas located at IR1, IR2, IR5 and IR8. Two new underground caverns and associated surface facilities have been built for the ATLAS experiment at IR1 and the CMS experiment at IR5. These zones were designed around each experiment, but also had to take into account the existing local structures. The layout and construction of the caverns and surface buildings are described above in Chap. 2. The experiments at IR2 (ALICE) and at IR8 (LHCb) will reuse the existing caverns built for the LEP experiments. In both cases only minor modifications to the underground caverns and buildings have been necessary. However, a major rearrangement of the infrastructure is needed and the consolidation of the existing infrastructure left from LEP is also an important consideration. The fifth experiment of the initial programme is TOTEM which will be installed at IR5 together with CMS.

ATLAS is a very large volume experiment which will have to be assembled for the first time in the underground cavern, as there is no hall at CERN large enough to make a pre-assembly. This has been taken into account as far as possible in the design of the new experimental area at Point 1. When considering the experimental area for the CMS detector, the main constraints are given by the construction and the installation of the magnet and the necessity to provide adequate and safe working conditions during the fabrication, assembly and installation periods. Unlike ATLAS the experiment can be almost completely assembled and tested in the surface hall and will be lowered 100 m to the underground cavern in large elements of up to 2000 tonnes each.

ALICE will not only reuse the experimental area at Point 2, but also the large solenoid magnet built for the LEP experiment L3. In addition, ALICE is building a large dipole spectrometer magnet (weight ~1000 tonnes) with a room temperature water-cooled coil, which will be assembled in the UX25 cavern and finally installed alongside the L3 solenoid. LHCb is a smaller experiment similar to those installed at LEP, but it is also based on a ~1000 tonne spectrometer magnet of a similar size and design to that being built by ALICE. This magnet will also be assembled and tested underground for the first time in the UX85 cavern.

10.2 NEW EXPERIMENTAL AREA AT POINT 1 FOR ATLAS

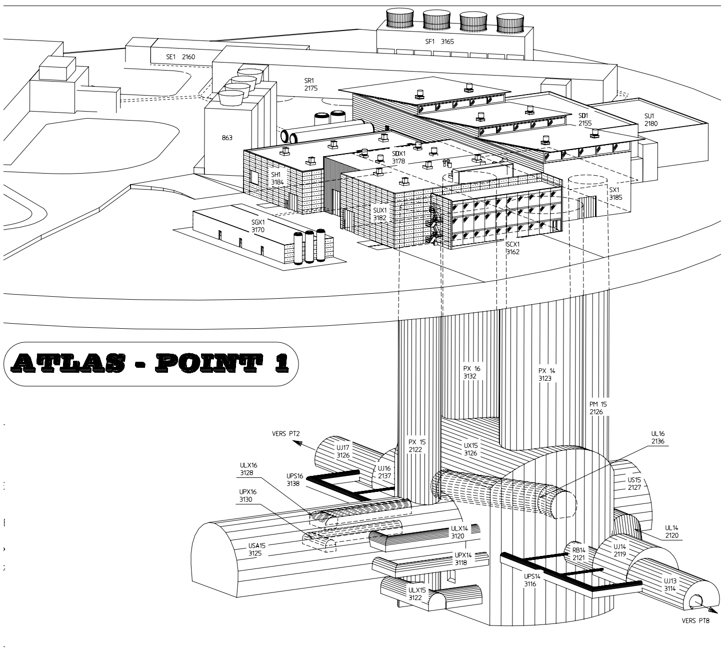

Figure 10.1: The ATLAS experimental Area at Point 1

10.2.1 Underground Caverns and Equipment

Experimental cavern UX15

The UX15 experimental cavern is located below the SX15 building, and linked to it via the PX14 and PX16 shafts. It has its axis parallel to the beam tunnel, between the previously existing US15 cavern on one side and the PX15 shaft and new technical cavern USA15 on the other side.

The UX15 cavern has a maximum internal length of 53 m, an internal width of 30 m and a maximum internal height of 34.9 m. It has an inner lining of reinforced concrete, comprising plain vertical sidewalls of 2 m thickness, curved vertical end-walls of 1 m thickness and a curved roof of 1.3 m thickness. The floor of the cavern consists of a 5 m thick slab of reinforced concrete, but has several trenches and channels cast into it, mainly for the collection of a possible large volume spill of liquid argon from the ATLAS detector. The floor slab is horizontal, thus the foundations for the detector feet will be inclined via the so called “bed-plates” in order to follow the slope of the beam.

The top of the vertical sidewalls include continuous concrete beams to support the crane rails for two 65 tonne capacity overhead cranes. At either end of the cavern, at the entrances of the beam tunnel, concrete elements of the low beta shielding have been cast integrally with the end-walls and are supported by concrete columns from the cavern floor.

The ULX15 liaison gallery provide personnel and equipment access into the UX15 cavern between the bottom of the PX15 shaft at ground floor level of UX15. The gallery is a 3.8 m wide by 3 m high horseshoe shaped tunnel and is provided with a 0.3 m thick inner lining of reinforced concrete.

Figure 10.2: The UX15 cavern for the ATLAS experiment shortly after reception by CERN from the civil engineering contractor

Service cavern USA15

The USA15 service cavern is located below the pre-existing PX15 shaft, with its axis perpendicular to the beam tunnel, adjacent to the new UX15 cavern. The cavern has a diameter of 20 m, a height of 13.5 m and a length of 62 m. The cavern has an inner lining of reinforced concrete of 0.6 m thickness. The invert of the cavern is curved and is filled with reinforced concrete to create a floor slab of a maximum thickness of 2.5 m.

The rear part of the cavern is equipped with an internal mezzanine floor of reinforced concrete, supported on the cavern sidewalls and on two rows of reinforced concrete columns. A 1 m wide by 2.2 m high personnel passage was constructed to provide an emergency escape passage from the rear end of the cavern to the access point of the UPX16 personnel access gallery. A crane beam for a 10 tonne capacity crane is installed in the apex of the cavern, running from the intersection with the PX15 shaft back to the rear end of the cavern.

The floor of the front part of the cavern is lowered in order to take the bottom of the PX15 shaft to the floor level of the UX15 cavern. Sumps for clean and waste water have been constructed at the low point of the underground complex, and water is pumped up the PX15 shaft to the surface. In addition, two cable galleries, named TE 14 and 16, run out of the floor of the USA15 cavern and into the UX15 cavern at low level. Each has a chicane for radiation protection purposes.

The wall between UX15 and USA15 is 2 m thick. It incorporates nine holes with diameters between 200 and 300 mm to permit short routing of trigger cables from the ATLAS detector to the acquisition racks located close to this wall in USA15. The UPX14 and UPX16 access galleries provide personnel access between the UX15 cavern and the USA15 cavern at the ground floor level of USA15. The galleries are 2.2 m wide by 2.2 m high horseshoe shaped tunnels.

The ULX14 and ULX16 liaison galleries provide connections for services between the UX15 cavern and the USA15 cavern at intermediate floor level of USA15. The galleries are 2.6 m wide by 2.6 m high horseshoe shaped tunnels and are provided with a 0.25 m thick inner lining of reinforced concrete.

Given the thickness of the walls and the geometry of the linking galleries, the radiation level has been estimated to be low enough (below 10 μSv/h) in order to allow access to the USA15 cavern during LHC runs up to the ultimate energy and luminosity [1].

Service cavern US15

The previously existing US15 cavern is shared with the LHC machine. The 2nd floor will be partially occupied by ATLAS to locate 60 racks [2], mainly for inner detector power supplies. The ground floor also houses the soap tank for the foam fire extinguishing system. The US15 service cavern is a non shielded zone and therefore not accessible during LHC operation with beam.

10.2.2 Electronic Racks

The UX15 experimental cavern where the ATLAS detector is installed constitutes a hostile environment where standard and non-standard racks and crates will be installed around the muon spectrometer. These racks will not be accessible during the operation of the LHC and will have very limited access during the short shutdowns.

It is planned to install some 100 racks of various dimensions for a variety of components either related to the control of the detector or to safety systems. The USA15 technical cavern will accommodate approximately 245 standard racks on two-levels, while the US15 technical cavern will house 60 racks for ATLAS. The SDX1 building on top of the PX15 shaft will provide space for up to 100 standard racks over two levels.

10.2.3 Cabling Infrastructure

To transmit all the information ATLAS will be handling, some 50 000 cm^2 of cable section and 10 km of cable trays will be needed. The cables for the transmission and acquisition of data will be of five types: multi-fibre optics, multi-conductor signal cable, multi-coax signal cable, multi-coax high-voltage cable and multi-conductor low-voltage cable for the supply of the electronics. The total section of cable linking the detector to the USA15 racks is estimated to be around 37 000 cm^2, with an average length of 130 m. Those linking the detector to the racks in the UX15 cavern will have an aggregate section of some 10 000 cm^2 (50 m long), and the cables for the trigger will need some 3 000 cm^2 of section (60 m long).

10.2.4 Detector Gas Infrastructure

The provision of gas for the detector is organized with the following infrastructure:

SGX1 gas building

This building has been conceived specifically for the storage, distribution, and mixing of inert and flammable gases in accordance with CERN regulations.

The ceiling of this building is divided into 16 separate sections; in such a way that each of the sections can act as deflagration vents. This type of construction reduces the risk of injuries to personnel working inside the building should deflagration or explosions occur. In addition to this, the building is divided into six different rooms in order to minimize the risks of flammable gas leaks.

A bundle of 34 pipes of various dimensions runs between the SGX1 and SDX1 buildings. These pipes will be extended down the PX15 shaft, into the gas room on the second floor of the USA15 cavern. From there, another 54 pipe bundle goes to manifolds on the walls of the UX15 cavern and finally the gas racks of the detectors.

All distribution pipelines are made in stainless steel. In accordance with TIS prescriptions for gas piping and pressurized pipes, all the welds are X-rayed and pressure-tested. In total, approximately 16 km of tube (all sizes) will be installed.

10.2.5 Cryogenic Infrastructure

The ATLAS detector includes two independent systems requiring cryogenic technologies: the superconducting magnets and the liquid argon calorimeters.

ATLAS magnet system

The ATLAS experiment houses three different magnet systems; a barrel toroid, consisting of eight coils housed in individual vacuum tanks, two end-cap toroids, each consisting of eight coils housed in a common vacuum tank and a central solenoid. A summary of the main parameters for each of the magnet systems is given in Tab. 10.1.

The central solenoid is cooled via the thermal siphoning method similar to that used for the CMS solenoid, while the three toroid systems are cooled by forced flow indirect cooling.

Table 10.1: Main cryogenic parameters of ATLAS magnets

	Cold mass (tons)	**Stored energy (MJ)**	**Static heat load (W @ 4.5 K)**	**Dynamic heat load (W @ 4.5 K)**
Barrel Toroid	370	1080	660	350
End-Cap Toroids	160	206	180	110
Solenoid	5.4	38	80	80

For the three toroid magnets the liquid helium to be circulated is taken from the bottom of a phase separator dewar by a liquid helium pump (1.2 kg/s at 400 mbar). This helium is then distributed over 10 parallel cooling circuits and passed through heat exchangers which are placed in contact with the cold masses of the magnets. The helium gas / liquid mixture coming from the heat exchangers is returned to the phase separator dewar. A 6 kW (at 4.5 K equivalent) refrigerator re-liquefies the gas from the phase separator and sends it to an 11 000 litre buffer. The liquid from this buffer is used to regulate the liquid level in the phase separator. The intermediate dewar provides a two hour cooling capacity, sufficient for a slow ramp-down of the magnets. To guarantee the functioning of this system there is a back-up pump and a no-break power supply.

The thermal shields of the magnets are cooled by a separate 20 kW (40-80K) helium refrigerator, which will also be used for the cool down of the cold masses. This delivers 60 kW of cooling power when boosted by liquid nitrogen.

After surface tests, the magnets will be assembled in the experimental cavern, where the first functional test of the complete ATLAS magnet system has been planned for 2006.

ATLAS calorimeter system

The ATLAS liquid argon calorimeter is housed in three independent cryostats: one barrel cryostat and two end cap cryostats. The main parameters of the cryostats are given in Tab. 10.2.

Table 10.2: Main cryogenic parameters ATLAS Calorimeter Cryostats

	Cold vessel volume (m3)	Weight of full cryostat (tons)	Number of signal wires	Static Load (kW)
Barrel	58	203	130000	1.8
End Cap	43	269	50000	2.5

Each of the argon baths of the three calorimeter cryostats is connected to an expansion vessel which is placed away from the cryostat at a higher level. The temperature in this expansion vessel and in the cryostat itself is regulated to be 87.3 K, creating an argon bath which is sub-cooled by 5 to 8 K. This sub-cooling is needed to avoid the formation of argon gas since bubbles would have fatal consequences for the high voltage system present in the cryostat. The argon baths are cooled by forced flow liquid nitrogen passing through heat exchangers placed in the baths. The liquid nitrogen is taken from a phase separator by a nitrogen pump which circulates the nitrogen through the heat exchangers. The mass flow and pressure of the nitrogen can be regulated for each heat exchanger individually. The nitrogen mixture coming from the heat exchangers is returned to the phase separator from where the gaseous nitrogen is sent to a nitrogen refrigerator (20 kW at 84 K equivalent).

The calorimeter cryogenic system has to function continuously over the complete lifetime of the ATLAS experiment. To guarantee this uninterrupted operation the nitrogen refrigerator has been backed-up by two 50 000 litre nitrogen storage tanks, which will supply the necessary cooling power in case of non-availability of the nitrogen refrigerator, and the nitrogen circulation is assured by two back-up pumps.

The three calorimeter cryostats will be tested individually before being lowered into the ATLAS experimental cavern. The complete system should be operational in the underground area by the end of 2005.

10.2.6 Surface Buildings and Equipment for ATLAS

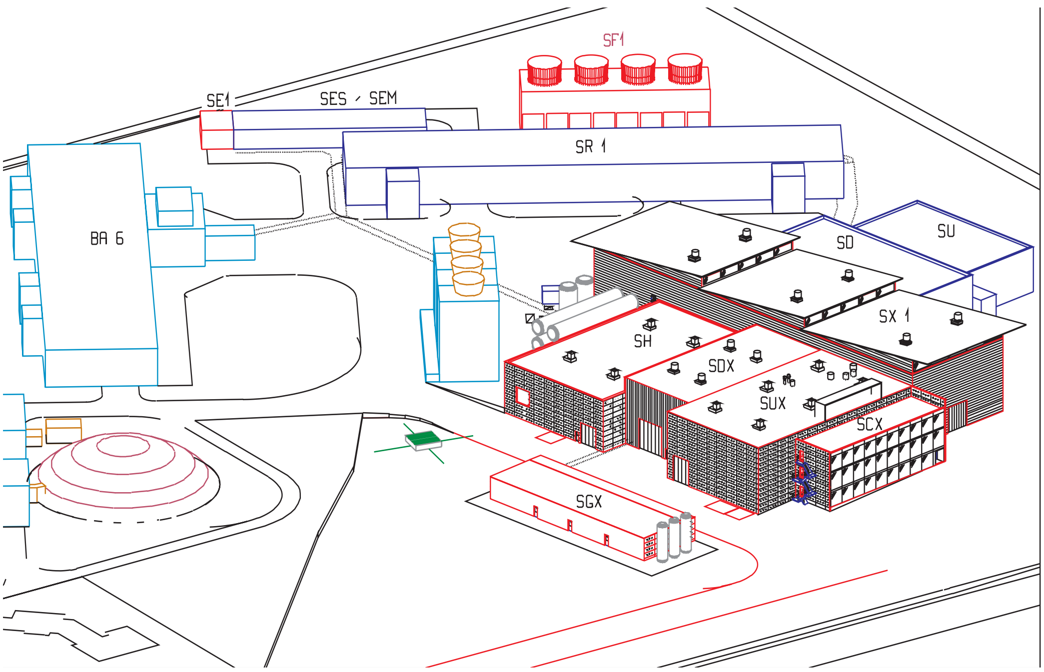

Figure 10.3: Layout of the surface buildings at Point 1

Assembly building SX1

The SX1 assembly hall is a steel-framed building comprising main columns (9 m centre to centre) supporting the crane girders, the roof and the side sheeting, together with secondary columns (4.5 m centre to centre) supporting roof and side sheeting. The roof structure is in lattice frames and the building is clad in steel profiled roof sheeting and timber wall panelling.

The main dimensions of the building are an internal length of 84 m, a width between the internal faces of the main columns of 20 m, with an internal height of 14.5 m to the lower eaves and 17.5 m to the higher eaves. The building is located over the PX14 and PX16 shafts.

The building is equipped with CERN's highest capacity overhead crane having two 140 tonne capacity hoists installed, each with a hook height of 9.3 m. The secondary crane, with 20 tonne capacity hoist, has a height under the hook of 6.2 m.

Special features of the building include a removable roof section and concrete beams over the PX14 and PX16 shafts.

Building for the collaboration and control room SCX1

The SCX1 control room building is a three-storey concrete and steel-framed structure. The main dimensions of the building are an internal length of 30 m, an internal width of 8.8 m and an internal height of 10.9 m. The front wall facing the Alps is made of glass panels. The building is equipped with an internal lift and staircase as well as exits from each floor to an external emergency staircase. The ground floor is intended to be the control room proper, but until 2006 it will be used as a CAD room for the ATLAS Technical Coordination. The first and second floors are to be used as offices.

The SUX1 ventilation building

The SUX1 ventilation equipment hall is a concrete box with two compartments and is constructed with reinforced concrete walls. The building houses ventilation equipment in the bigger of the two rooms and plant for chilled water production in the smaller room. The main dimensions of the building are an internal length of 40 m, an internal width of 23 m and a maximum internal height of 13.75 m from the lowest floor level to the underside of the roof. An 8 tonne capacity overhead crane is installed in the smaller of the two rooms, with a height under the hook of 9.6 m. The capacity of this crane had to be reduced to 4.5 tonne as a result of late modifications to the supporting wall, where large holes for cooling pipes and electrical services have been added.

Access building SDX1

The SDX1 access building to the USA15 cavern is situated on top of the PX15 shaft. The main dimensions of this building are an internal length of 34 m, an internal width of 17 m and an internal height of 12.3 m from floor level to the underside of the roof. The building provides personnel and services access to the underground area via the PX15 shaft. A 16 tonne capacity overhead crane is installed in the building with a height under the hook of 9 m.

Helium compressor building SH1

The SH1 cryogenic equipment hall is a concrete box, constructed with reinforced concrete walls. The main dimensions of the building are an internal length of 40 m, an internal width of 25 m and an internal height of 9.4 m from floor level to the underside of the roof. A 10 tonne capacity overhead crane is installed in the building with a height under the hook of 6 m.

Gas for experiment building SGX1

The SGX1 gas supply building has been constructed with reinforced concrete walls. The main dimensions of the building are an internal length of 40 m, an internal width of 10 m and an internal height of 4.5 m to the underside of the roof. The building comprises various rooms for storing, mixing, and controlling the supply of gas to the underground areas. The roof sections above the mixing room and the flammable gas room are designed to allow release of blast force in the event of an explosion.

Access control building SY1

The SY1 security control building is located at the entrance of the site to control site access. The main dimensions of the building are an internal length of 10.5 m, an internal width of 9 m and an internal height of 2.5 m. The main structure is in structural steel. The roof is made of lightweight, sandwiched, insulated steel sheeting, and the perimeter walls are of proprietary insulated panels with double glazed windows. This building is similar to existing LEP security control buildings.

Local computer building

The racks containing the computer for DAQ are planned to be installed in a two storey metallic structure, to be housed in the SDX1 building. Up to 100 racks can be accommodated there, with appropriate cooling and ventilation.

10.2.7 Safety at Point 1

Radiation shielding

The dominant source of the radiation in ATLAS comes from the proton-proton collisions at the interaction point. Other sources such as beam halo and beam-gas interactions are very small in comparison. Most of the collision products are absorbed in the calorimeters or in the copper absorber protecting the first machine quadrupoles. Gaps between calorimeters are the dominant source of the radiation field in certain regions. Careful consideration has been given to background rates, and activation of material. Steps have been taken to minimize them. The residual radiation in the adjacent building structures has been simulated using realistic wall thicknesses and openings for cable ducts.

In the surface building SX15, with the access shafts covered with a shielding consisting of concrete beams, 120 cm high over both shafts, the dose level will be substantially below the limit of 1μSv/h in a surveyed area. This building will therefore be accessible at all times [1]. The dose outside the building at the site fence will be below the 0.1μSv/h required for a public area, even at ultimate LHC performance.

The layout of the passages between the experimental cavern UX15 and the lateral equipment cavern USA15 gives sufficient attenuation factors such that the dose rate in the most disadvantaged part will remain below the limit of 10μSv/h as required for a controlled area. This means that this technical cavern will be accessible for authorised and monitored personnel at all times [1].

The lateral cavern US15 is shared with the machine. As it is connected to open passages towards the machine this cavern is only accessible with no beam in the machine. Since there will be no activation in this area, access can be granted immediately after a beam dump and declaration of the appropriate access conditions.

Ventilation

The concept, size and mode of operation of the air-conditioning systems for the ATLAS experiment proper, and its underground and surface auxiliary buildings, have been designed taking into account the interconnections amongst the underground structures and their required accessibility. The air-conditioning systems will perform the heating, ventilation, air cooling, and the safety functionalities (smoke control and gas extraction) related to the occupation and usage planned for each particular building. Various emergency scenarios have been considered, and the corresponding operation modes have been implemented. For example, in the event of a gas leak, or detection of smoke, the flow of air in the UX15 cavern can be increased from 45 000 m^3/h to 90 000 m^3/h, while gas extraction systems continue to remove 21 000 m^3/h from the lowest part of the cavern. Similar scenarios exist for the USA15 cavern.

10.3 THE NEW EXPERIMENTAL AREA AT POINT 5 FOR THE CMS EXPERIMENT

10.3.1 Introduction

The CMS experiment will be housed at the LHC Point 5 area located at Cessy in France [3][4]. When considering the experimental area for the CMS detector, the main constraints are given by the construction and the installation of the magnet and the necessity of providing adequate and safe working conditions during the fabrication, assembly and installation periods. Great effort has been made to balance the necessity and the convenience of a large experimental hall with the overall cost and with the basic limitations set by the LHC machine elements as well as the already existing LEP installations. Since the design of the experimental area for CMS was completed a second much smaller experiment TOTEM has been approved and will be installed in the same area. No additions or modifications to the infrastructure are needed.

The design of CMS is based on a large superconducting solenoid surrounded by an iron muon spectrometer. The 4 T field of the solenoid acts directly on the steel disks, which form the forward part of the iron yoke, thus creating a large magnetic pressure. To resist this force, only assembly based on 600 mm thick plates has been found to provide a satisfactory solution. The design of the barrel yoke consists of three layers built up of steel plates. The thickness of the inner layer is 295 mm, the middle and the outer layers being 630 mm thick each, weighing up to 40 tonnes per unit piece, which must be assembled to create the five rings of the muon spectrometer barrel. The coil, which will be built as a single unit weighing 220 tonnes, has to be inserted in the horizontal position into the central barrel ring of the yoke, YB0. The vacuum tank is then welded around the coil.

Carrying out this heavy assembly work in the underground cavern was excluded for the following reasons. It would require a very large cavern with one additional large access pit and two 80 tonne cranes, one at each end of the cavern, since large pieces cannot be transferred over the detector unless the height of the cavern is substantially increased. Even if these requirements were met, the detector construction work would have to proceed in series, because of the limited length of the cavern along the beam line, and the fact that most of this work is not compatible with the cleanliness required for the assembly of the superconducting coil. The duration of the construction of the magnet in the underground area was estimated to take at least a year longer compared for assembly on the surface. Furthermore, the duration of this activity would have to be counted from the finishing date of the underground area. Only then could the assembly and completion of the sub-detectors be performed. Such a scenario proved to be unacceptable. Finally, the safety risk for personnel and equipment would inevitably be greater.

The alternative solution is to carry out as much detector assembly work on the surface; this could be done in parallel with LEP operation and during the construction of the underground cavern after the LEP closure. Several sub-detectors, such as the barrel and end-cap muon chambers and part of the calorimetry, will be installed in the yoke at the surface, saving additional time in the underground area. Moreover, assembling and testing the CMS detector on the surface provides the additional advantage of rehearsing the risky operations on the surface and being able to cope with the unplanned spread of sub-detector delivery. However, a larger surface hall is required temporarily, together with the hiring of heavy lifting equipment at some point in time.

The CMS experimental area at Point 5, both surface buildings and underground caverns, is shown schematically in Fig. 10.4.

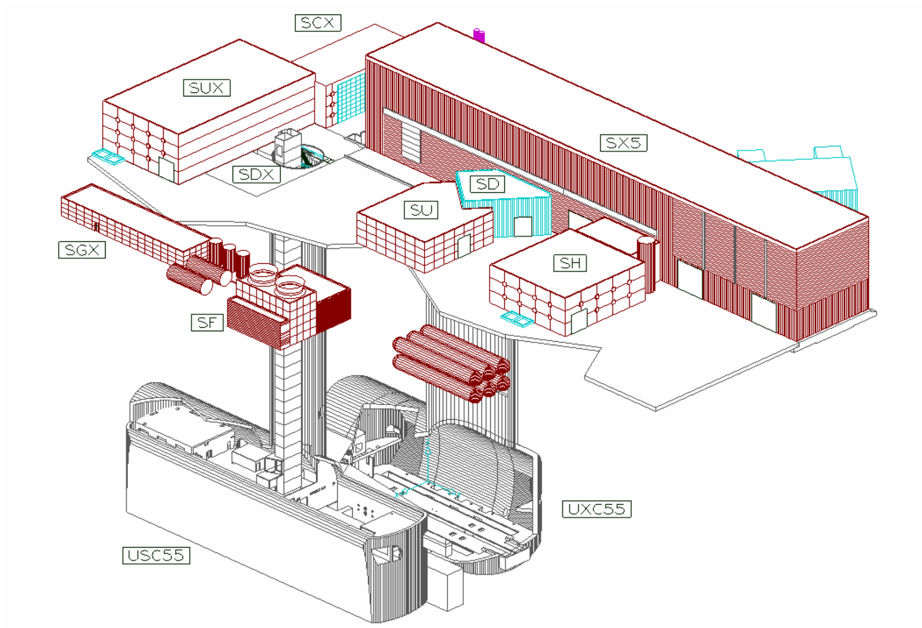

Figure 10.4: The CMS experimental area

10.3.2 Surface Buildings

Building dimensions

The surface building requirements of CMS are dominated by the need to carry out a complete assembly and test of the magnet on the surface, which requires a minimum height of 18.3 m under the crane hook. This implies a 23.5 m high building. The construction of the magnet sub-assemblies, too large to transport by road, requires a 100 m long, 23.5 m wide assembly hall (SX5), which will be linked to the main access shaft (PX56) for installation underground after testing. In order to allow changing of the relative position of the large sub-assemblies inside the hall, two alcoves have been added, which locally increase the effective width of the hall. The hall is equipped with two 80 tonne overhead cranes and a heating and ventilation system, but has no general temperature stabilisation. Furthermore, the main assembly hall is complemented by a temporary appendix (SXL5) needed for the in-situ reinforcement of the conductor for the superconducting coil. The layout extends outside the Point 5 border established for LEP. In addition one of the existing LEP buildings (SU5) had to be moved.

Environmental impact

The CMS collaboration, together with CERN, was concerned about the environmental impact of the proposed assembly hall. The preparation of several of the sub-detector units is being made in existing CERN assembly halls. Road transport sets a strict limit to the size and weight of objects that can be transported. However, after the completion of the manufacturing, assembly and testing of detector components on the surface and their lowering to the cavern, the alcoves and the appendix SXL5 will be demolished and the height and the length of the assembly hall will be reduced to 16 m and 100 m respectively from its most extended dimensions of 23.5 m and 141 m.

10.3.3 Underground Caverns

General considerations

The basic design criteria for the integration of the CMS experimental cavern at Point 5, where the beam level is situated at a depth of 90 m, are:

- A longitudinally oriented cavern (UXC55) providing space for the withdrawal of the end-cap sections,
- One access shaft (PX56), centred on the beam line, permitting successive installation of the large detector pieces from one side of the cavern,
- A separate cavern (USC55), placed parallel to the main cavern and integrated with the LHC machine by-pass tunnel, housing the counting room (at a radiation-safe distance while allowing the shortest possible routing of the cables) and the technical services (cryogenics, gas, power supplies, cooling and ventilation),
- One personnel access shaft (PM54) serving both caverns USC55 and UXC55, thus avoiding a dead-end in the latter,
- The preservation and use of the existing LEP installations, as far as possible.

The absence of existing major underground structures at Point 5 gave a certain freedom in the design of the overall layout of the experimental cavern. However, the unfavourable underground geological rock structure (compared to Point 1) and the location of the deep underground water layers had to be carefully examined prior to the final design. In particular, this resulted in choice of a 7 m thick separation wall between the two caverns (as compared to the minimum 3 m required for the radiation shielding). However, as a result, the service cavern will be permanently accessible, as a radiation controlled area.

Additional reduction of radiation doses will be provided by the intrinsic shielding offered by heavy objects such as the calorimeters and the magnet yoke and the use of mobile shielding around the beam line. The main access shaft is centred on the LHC beam line and must, therefore, have a mobile shielding plug of 2 m thick concrete, which will be situated at the surface level flush with the floor of the assembly hall. A 3 m thick shielding door will separate the access from the bottom the shaft PM54 to the floor of the main cavern.

It was essential that the design of the experimental area also include facilities to provide for safe and efficient working conditions during the installation and maintenance periods. The chosen scheme, in which all detector units and the magnet are fully assembled and tested on the surface and brought down into the experimental cavern with a minimum of further assembly work, has resulted in reduced dimensions of the underground cavern. An incorporation of a de-mountable platform into the main access shaft will separate the ventilation systems and will provide mechanical protection from falling objects. This platform is installed at the level of the ceiling of the cavern. A three level gangway system fixed to the cavern walls provides for unobstructed circulation and easy access to the two independent exits from the underground caverns.

Layout of the underground caverns

The main cavern UXC55, 26.5 m in diameter and 53 m long, is comparable in size and volume to the ex-LEP cavern at Point 2. The auxiliary cavern housing the counting room and the technical services as well as the LHC machine by-pass tunnel has an overall diameter of 18 m and a total length of 85 m. It is aligned parallel with the main cavern and separated by a 7 m thick wall. The thickness is primarily dictated by the required civil engineering structures and it largely offers appropriate radiation shielding. Two access tunnels, one from the auxiliary cavern (UP56) and one from the bottom of the shaft PM54 (UP55), join the main cavern at different levels. In addition, at the height of the beam, two smaller survey galleries interconnect the main cavern with the machine tunnel.

The main access shaft PX56 to the UXC55, 20.4 m in diameter, provides a net 14 m x 19.5 m opening for the installation of the magnet and the detector units. A second access shaft PM54, 9 m in diameter, provides lateral installation access at the floor level to the other end of the detector. This is necessary, since the limited crane clearance over the detector does not allow large objects to be transported between the two end-cap regions. Metal plates are embedded in the concrete floor inclined by 1.23% and thus running parallel to the slope of the beam line. In the central part of the cavern the floor level is lowered by 3 m in order to provide access under the detector for services. This volume is also connected to the counting room in the auxiliary cavern via three labyrinth tunnels to run cables and services.

The low-β quadrupoles, which penetrate into the experimental hall, are placed on a solid concrete platform in order to provide a stable foundation for the intersection elements. This concrete structure also serves as a radiation shielded alcove for the HF detectors, when the main end-cap sections are withdrawn for access.

The existing underground structures at Point 5, the access shaft PM56 and the junction UJ57 serving the LHC machine proper, have not been modified, since they are outside the boundaries of the new structures.

10.3.4 Infrastructure

Main UXC5 Cavern

Although the bulk of the heat load produced by the detector units will be removed by dedicated cooling arrangements, the environment in the experimental hall will play an important role in the long term stability of the detector. The ambient air in the cavern must be kept at a low humidity level (dew point 9 °C ± 1) and with a high degree of temperature stability (18 °C ± 1). In order to achieve this, a system of distributed ducts for the injection of air into the cavern has been designed to fit the walls behind the gangways. The gangways are arranged on three levels and aligned with the rack platforms attached to the detector. A series of stairs make it possible to access the protection platform in the main shaft PX56. The cavern is equipped with a 20 tonne crane having an effective hook-span of 17 m.

Auxiliary Cavern USC55

The auxiliary cavern USC55, which is horizontal (not aligned with the slope of the main cavern), is essentially divided into two sections: one for the counting room and the gas distribution system and one for the general detector services. In addition, the latter section will house the power supplies for the low-β LHC machine quadrupoles. The two sections, which are nearly identical in size, will be separated by the common access shaft PM54 and the personnel safe room.

The counting room, which is longitudinally centred with respect to the detector in the main cavern, has been designed to house approximately 250 electronics racks installed on a two-floor structure with separation walls. This cavern section also houses the gas distribution system. The 9 m diameter shaft (PM54) will give access to the two floors of the counting room, as well as to the floor level of the main cavern via a dedicated large shielding door in the separation wall. The access shaft is equipped with a fire protected 3 tonne lift and a staircase system, which will ease the installation of all counting room equipment and provide direct installation access to the main cavern floor level. The limited size of the access shaft does not allow installation of large prefabricated counting room modules. This is, however, not regarded as necessary since the cavern itself will constitute the 'housing structure' and will also allow the centralisation of the cooling, ventilation and power arrangements.

The other half of the auxiliary cavern will house the power supply and the cryogenic system for the magnet, part of the magnet quench protection system, the cooling and ventilation distribution systems as well as a few racks for the low-β LHC machine power supplies.

10.3.5 Cryogenic Infrastructure

The solenoid magnet of CMS has a cold mass of 225 tons and a nominal field of 4 T. The stored energy in the magnet is 2.6 GJ. The static heat load is estimated as 160 W at 4.5 K and the dynamic load as 365 W at 4.5 K. The heat load on the thermal screens (temperature 60-80 K) is expected to be 3 kW, while the current leads will need a liquid helium flow of 3 g/s. The magnet is cooled by the thermal siphoning principle; liquid helium is taken from a phase separator placed on top of the experiment to the bottom of the solenoid, from where it is distributed over heat exchangers placed in contact with the cold mass. The thermal load will create helium gas in the heat exchangers and the hydrostatic pressure difference creates a driving force circulating the helium through the heat exchangers back to the phase separator.

A 1.5 kW at 4.5 K equivalent helium refrigerator then re-liquefies the gas and sends it to a 6 000 litre intermediate storage dewar which provides a buffer volume guaranteeing a five hour cooling period. This is sufficient for the slow ramp down of the magnet, even in case of refrigerator failure.

The refrigerator system installation has been planned to cool-down the solenoid for the surface tests early in 2005 and, once the magnet has been lowered and reconnected, to provide cooling for cold tests in the underground experimental area which are planned for 2006.

10.3.6 Safety

The design of the experimental area has incorporated several specific safety aspects, such as:

- Fixed gangways and staircases for easy access at all levels in the underground caverns,
- Emergency escape routes at each end of the main cavern,
- Smoke extraction, in case of fire,
- Fixed and mobile radiation shielding surrounding the low-β quadrupoles and absorbers,
- A hard cover (removable platform), providing protection beneath the main access shaft.

The large capital investment and the unique nature of the CMS detector imply that a first class fire prevention and fire fighting system must be installed in the CMS experimental area. The global fire prevention in the experimental area is based on the correct choice of material, application of intumescent paint and the installation of permanent inertion and sniffer systems, all based around PLC architecture. The fire fighting system consists of hydrants / portable fire extinguishers, a water mist system and a high expansion foam system.

10.3.7 Other Surface Facilities

During the construction phase of the magnet and during the assembly phase in the surface hall other hall surfaces will be required on a temporary basis elsewhere on the CERN site for the storage, preassembly, and testing of the sub-detectors. Some of these sub-detectors require clean (e.g. Electromagnetic Calorimeter and Forward Hadronic Calorimeter) or very clean areas (e.g. for the tracker).

10.4 RE-USE OF THE POINT 2 EXPERIMENTAL AREA BY THE ALICE EXPERIMENT

10.4.1. The UX25 Underground Cavern

The ALICE detector will be installed at Point 2 of the LHC. This area was designed for the LEP, L3 experiment, but is ideally suited for the ALICE detector. Only very minor modifications are needed to the experimental cavern or the surface zone. The main access shaft (PX24) is 23 m in diameter and provides a 15 x 7 m^2 opening for the installation passage and space for counting rooms. The counting rooms are separated from the experimental area by a concrete shielding plug as shown in Fig. 10.5. The PX24 shaft is equipped with an 800 kg capacity lift and a separate staircase. The experimental cavern (UX25) is 21.4 m in diameter and was initially equipped with a 40 tonne crane, having a limited clearance over the L3 magnet.

The experimental area is dominated by the presence of the L3 magnet, which provides an 11.6 m long and 11.2 m diameter 0.5 T solenoidal field. The end-caps have a door-like construction. The magnet has an octagonal shaped yoke with the lower three octants embedded into the UX25 hall foundation. The door frames will support large beams traversing the L3 magnet, which will be used to support the ALICE central detectors.

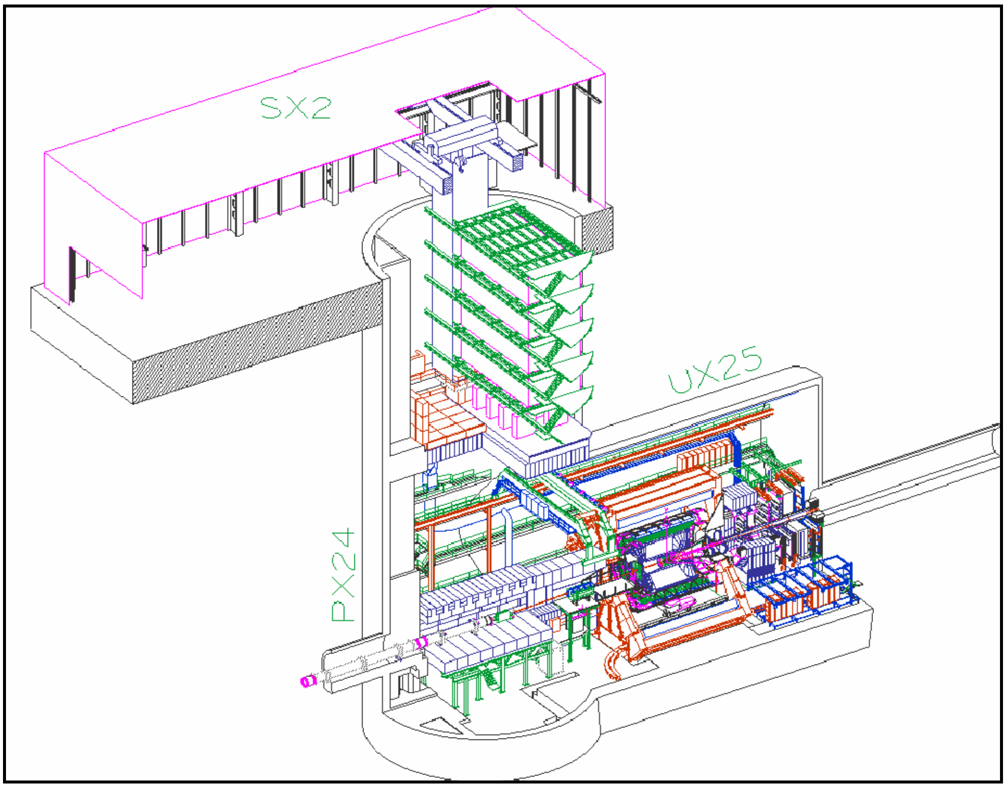

Figure 10.5: Basic layout of the underground structures at Point 2.

10.4.2. The Point 2 Surface Zone

The existing surface zone at Point 2 includes sufficient assembly hall space and storage areas (the 1350 m^2 SXL2 assembly hall and the SXS storage platform) to meet the essential requirements of the ALICE experiment and no new hall constructions will be necessary. The surface zone and existing buildings are shown in Fig. 10.6. The main access shaft (PX24) is covered by a 1790 m^2 building (SX2), equipped with a 63 tonne gantry crane. The existing gas distribution building (SGX2) can be used without any modification by the ALICE experiment. The Point 2 site has no specific office building, but instead a number of building-site barracks have been installed in a semi-permanent manner

10.4.3. Modifications to Point 2

The existing capacity of the infrastructure installations at Point 2, such as cranes, power, cooling and ventilation systems all meet the requirements of the ALICE experiment. However, an extensive repair and maintenance programme is necessary in order to consolidate the existing infrastructure and guarantee a further 15 year operation.

Initially, it was proposed to construct a second access shaft for the UX25 underground cavern. However this has been avoided by sharing the PM25 shaft for access to the LHC tunnel and the UX25. This has, furthermore, been facilitated by enlarging the chicane between the US25 and UX25 caverns. In addition, a new 2 x 20 tonne crane has been installed in the UX25 cavern, with a clearance of 3 m over the L3 magnet. This permits the PX24 shaft to be used to transport large items to the RB26 side of the L3 magnet.

On the surface the construction of a roof between the SA and SF buildings has created a 250 m^2 cold storage area, which avoids using the SXL2 and SX2 assembly halls for storage. In agreement with the LHC project, the ALICE collaboration can also use half of the SA building for temporary storage.

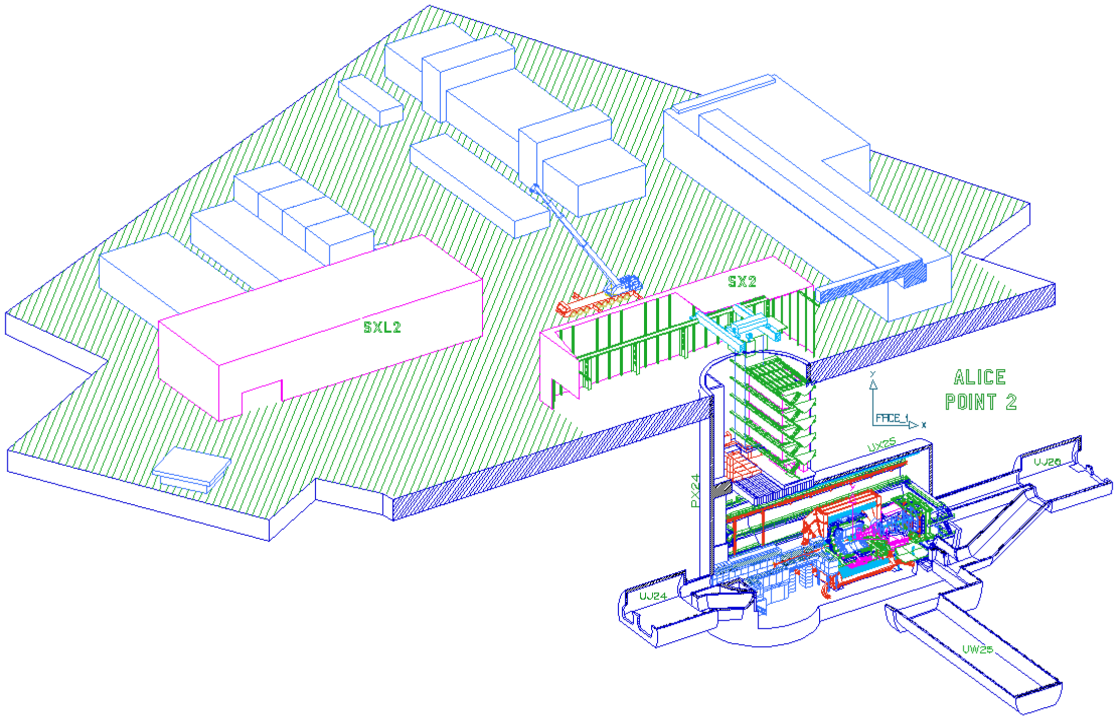

Figure 10.6: The Point 2 surface zone indicating the main assembly halls SXL2 and SX2.

10.4.4. Radiation Shielding

The more severe radiation environment of LHC compared to LEP will require reinforced radiation shielding and changes to the present access. The reinforcement of the shielding is not related to the ALICE experiment, since even without any experimental installation at Point 2 the shielding would have to be upgraded to LHC standards. The integration of the additional shielding is the dominant complication in the conversion of the Point 2 experimental area and does impose a number of constraints on the layout of the Alice detector.

Extensive simulations [5] have shown that additional shielding of the beam line on the RB24 side and the reinforcement of the shielding plug in the PX24 shaft, are necessary in order to provide a satisfactory shielding situation at Point 2. The beam line penetrating into the UX25 will be surrounded by a minimum of 1.6 m of concrete as shown in Fig. 10.7.

10.4.5. Infrastructure for Services

The four counting room levels in the PX24 access shaft provide space for a maximum of 120 racks (see Fig. 10.8). Each counting room is equipped with water cooling circuits and an air cooling capacity of 50 KW. The different levels can be reached by a dedicated lift installation and two independent staircases. The false floor of each level is directly connected to a vertical service shaft, which permits easy access for installation of cables. Fig. 10.8 also shows the routing of the services.

The shielding plug separating the public area from the radiation controlled cavern, also serve as a convenient area for the gas distribution racks. All services enter the experimental area via two chicane arrangements incorporated at the circumference of the shielding plug. The UX25 cavern has a system of fixed cable trays covering the entire length of the cavern and the part of the PX24 access shaft below the shielding plug.

The main control room ACR (ALICE control room) is situated in the SX2 hall and provides a 150 m^2 working area, divided into two different sections; control room area and a computing room.

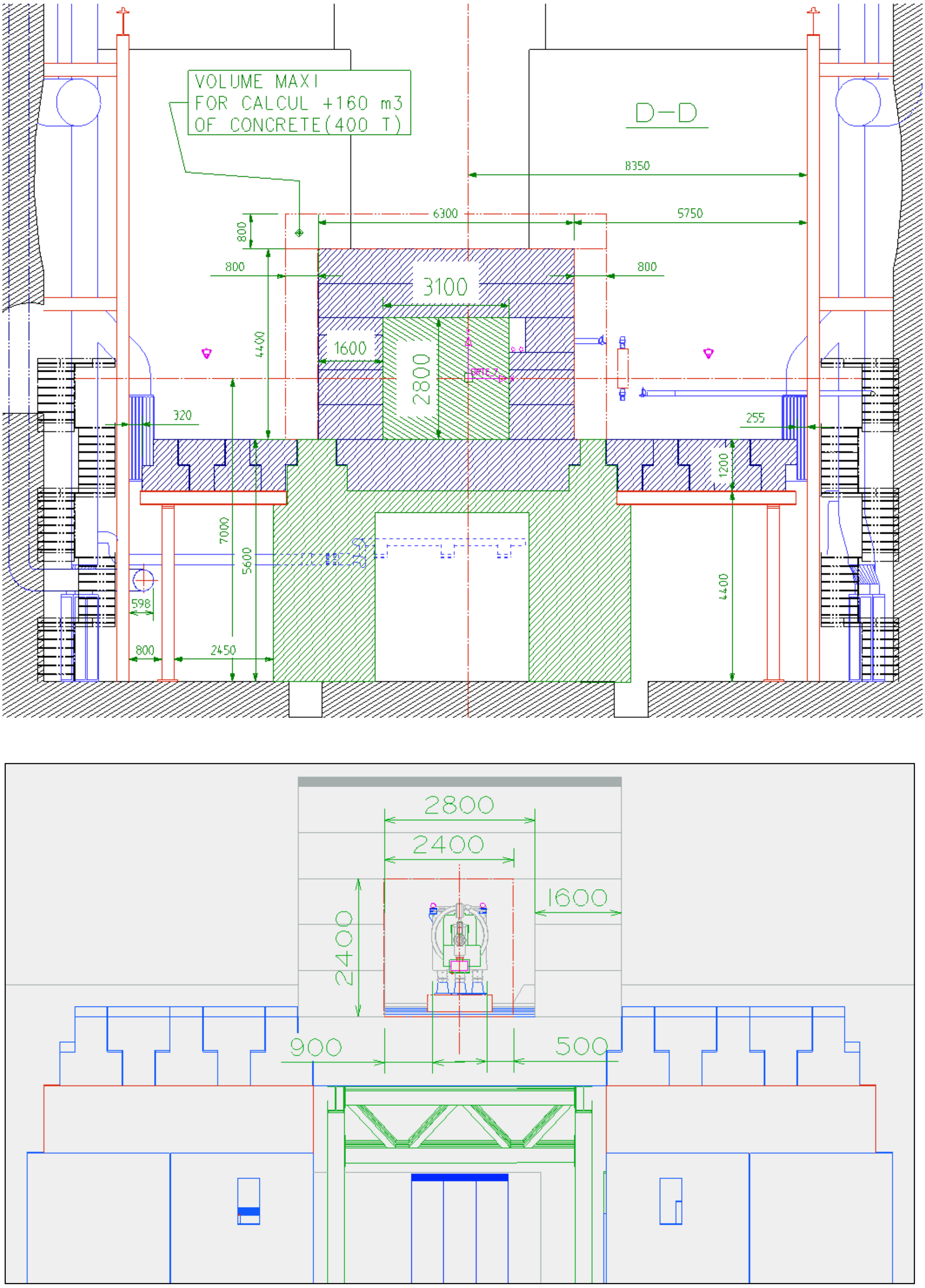

Figure 10.7: Shielding arrangement for the beam line in UX25.

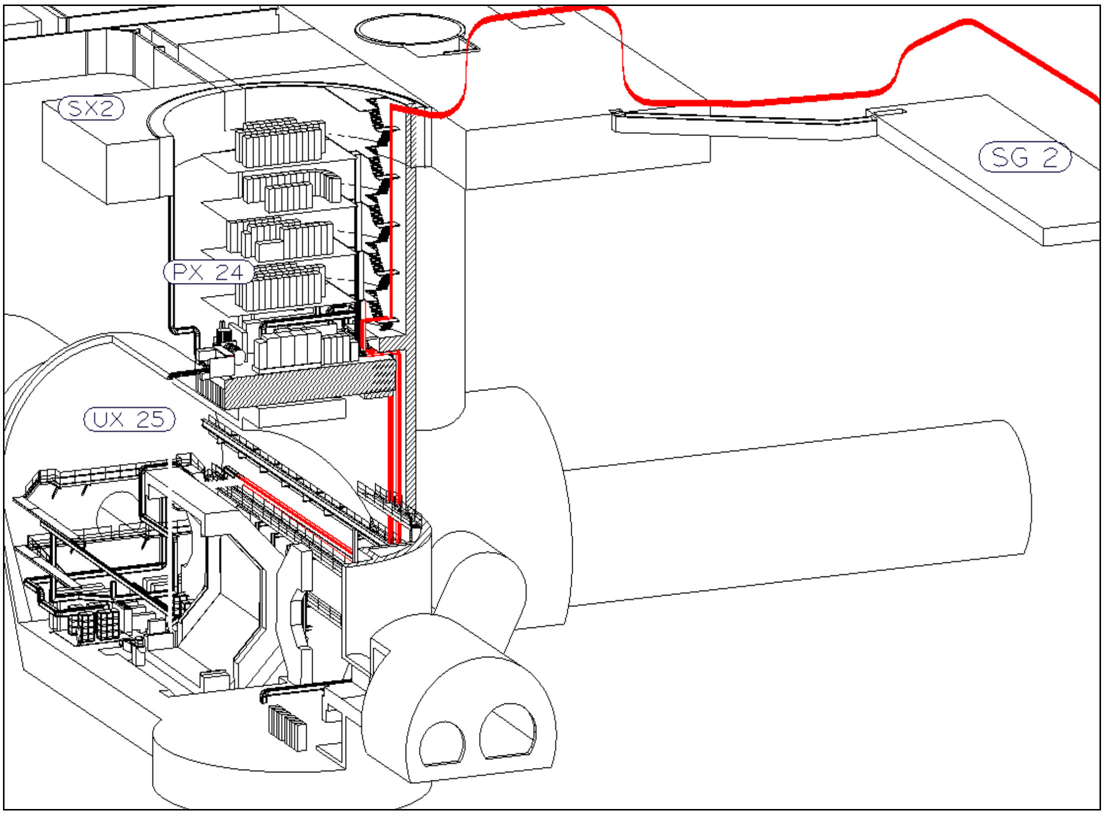

Figure 10.8: Routing of services in the Point 2 experimental area

10.4.6. Safety Installations

The area safety installations are designed to give global protection of the surface and underground areas independently of the dedicated safety installations needed for the experimental installations.

The surface assembly halls (SX2 and SXL2) are equipped with smoke detector systems placed near the roof and general emergency stops. Depending on the nature of the activities inside the halls, local detection systems or emergency stops are added as a complement to the general facilities.

The general safety arrangements in the underground cavern UX25 reflect the restrictions set by the underground environment. In addition to general smoke detector systems and general emergency stops the cavern is equipped with an emergency evacuation alarm. Two independent escape routes are available; via the lift/staircase system in the PX24 shaft or via the lift/staircase system in PM25. Special panels indicate the escape routes, which stay visible even during limited visibility.

The underground cavern is also equipped with a water flooding detection placed at the bottom of the PX24 lift shaft.

10.5 RE-USE OF THE POINT 8 EXPERIMENTAL AREA BY THE LHCb EXPERIMENT

10.5.1 Introduction

The Large Hadron Collider Beauty Experiment (LHCb) for precision measurements of CP–violation and rare decays [6][7], is to be installed at the existing experimental area at LHC Point 8.

The LHCb Detector is a single-arm spectrometer motivated by the production of the beauty particles and anti-particles in the same forward or backward cone. Fig. 10.9 is a side view of the LHCb detector in the y-z plane. Where the LHCb coordinate system is a right handed coordinate system with z-axis pointing from the interaction point towards the muon chambers along the beam-line. The y-axis is pointing upwards. The x-axis is pointing towards the outside of the LHC ring.

The detector covers the angular region from 10 mrad to 300 mrad in the horizontal (x-z) plane and from 10 mrad to 250 mrad in the vertical plane (y-z) plane. The detailed description of the sub detectors are presented in the LHCb technical design reports submitted to the LHCC.

Interaction Point

The characteristics important for the layout of the experimental equipment around IP8 [8] are summarised in Tab. 10.3.

Table 10.3: IP8 characteristics

Displacement from the centre of cavern towards Point 7	11 220 mm
Tilt angle of the beam-line – Lowest point towards Point 7	3.6 mrad
Beam crossing angle	± 285 μrad
Beam crossing plane	Horizontal
IP beta	1 → 35 m
Design Luminosity (mean)	2 x 10^{32} cm^{-2} s^{-1}

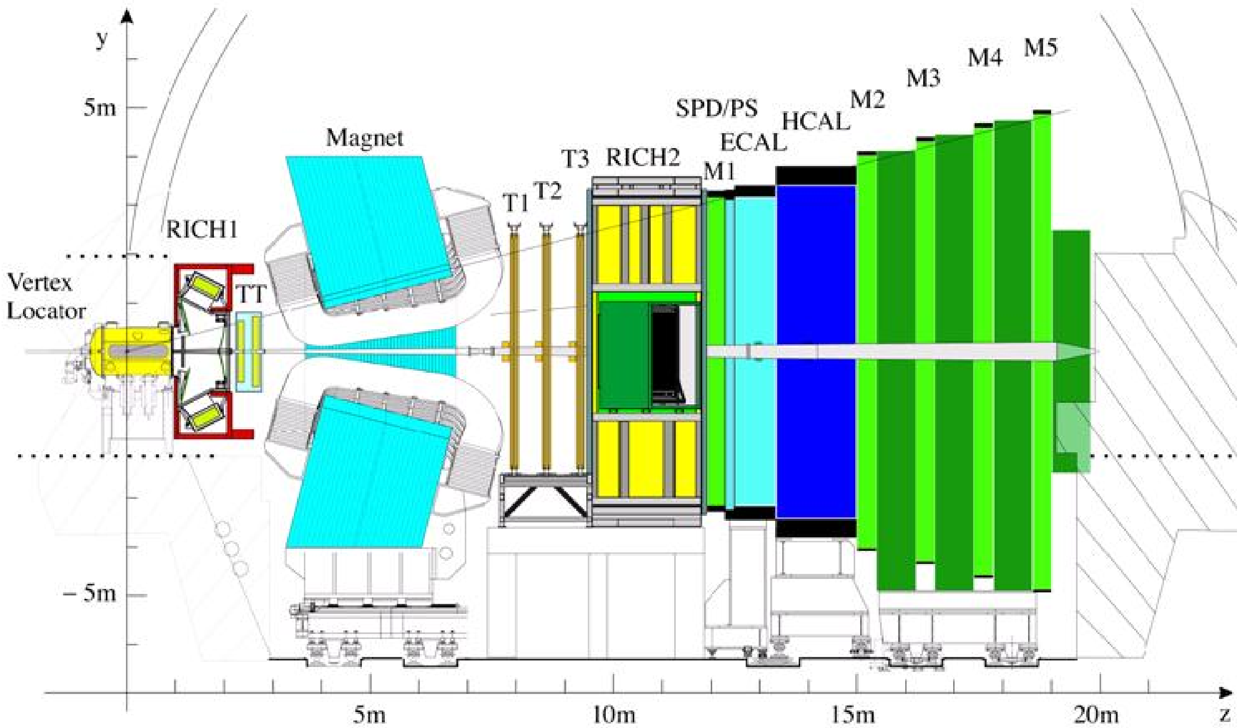

Figure 10.9**:** Side view of the LHCb detector in the y-z plane.

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10.5.2 The UX85 Underground Cavern and Modifications

The existing UX85 cavern at Point 8 is located at a depth of 110 m below the surface. Fig. 10.10 is an axonometric view showing the underground areas.

Personnel access is via the PZ shaft, while for lowering the equipment the 10 m diameter PX shaft is used. The existing cranes include an 80 tonne hook at the PX shaft and a 40 tonne and 2x40 tonne hooks in the UX85 area are all reused.

All of the existing infrastructure equipment and facilities, originally provided for the LEP experiment DELPHI are re-used by the LHCb experiment. However, a few major modifications were required. The most important concerns the head wall at the PZ end, which has required major consolidation work using a concrete structure to replace the original metallic structures.

In addition, in order to allow access to the mobile counting rooms which have been withdrawn to the PZ end of the cavern, the UX85 cavern has been divided into two distinct areas: a detector area and a protected area where the counting rooms and all the control racks are located. The protected area will be accessible when the LHC is operating. The third major modification concerns the installation of a cryogenic unit for the LHC machine at the end of the UX85 cavern beside the LHCb detector.

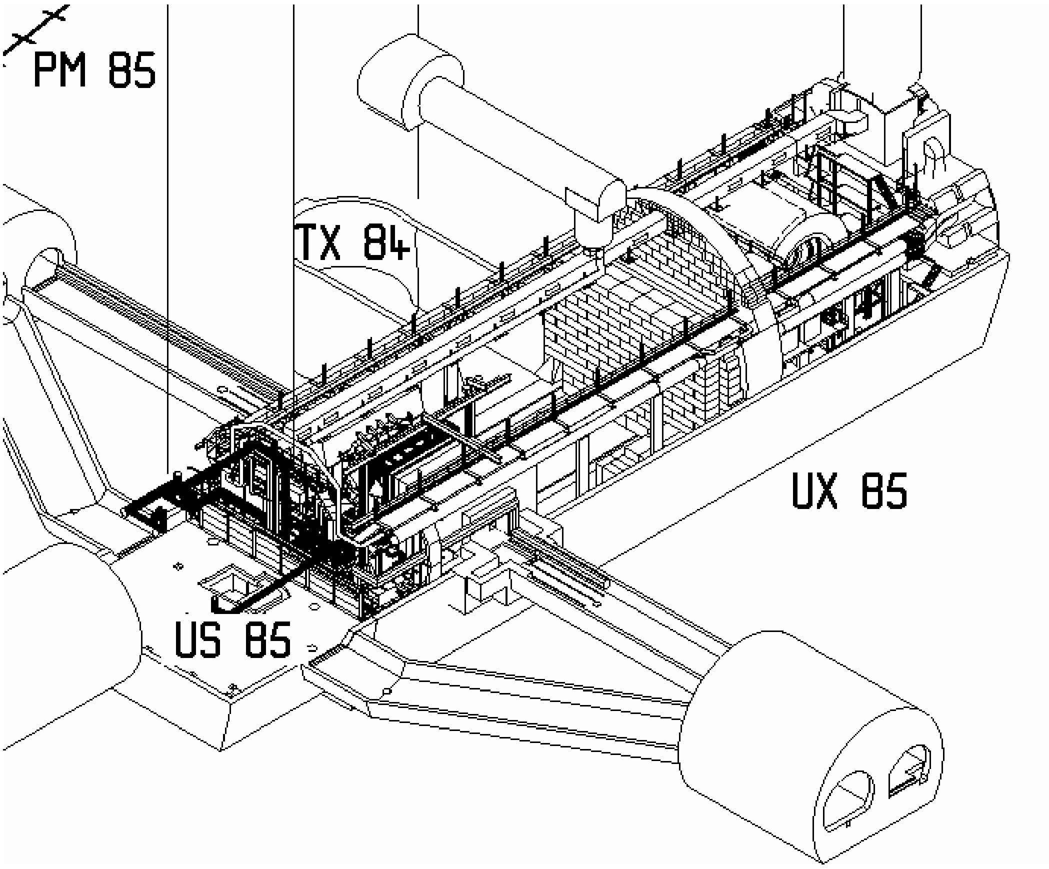

Figure 10.10: Axonometric view of the underground areas at Point 8

Layout

Fig. 10.11 shows the layout of the LHCb detector and LHC cryogenic units as they will be installed in the cavern. The first major component of LHCb in the cavern is the warm dipole magnet [9], which will be assembled in the underground cavern during the transport and the transfer of the LHC components for the sectors 7-8 and 8-1. This requires a temporary bridge across the experimental area. The installation of the rest of the LHCb detectors will follow and the global commissioning is planned from September 2006 until March 2007.

The main radiation shield

The UX85 cavern is divided into two distinct areas, a protected area and a detector area. A large radiation shielding wall [10] is required for that purpose in order to ensure that access to the protected area will be possible under all LHC operating conditions. Radiation simulations [11] using FLUKA code show that a concrete wall 3 m thick is needed as a minimum radiation protection against the total loss of a maximum intensity LHC beam. These simulations are very conservative, not only because the total loss of every proton in the LHC beam is very unlikely but also because it is assumed that the loss occurs on an 'ideal' target in which every proton can interact, but which provides no lateral shielding.

A modular shield consisting of a total in the order of 3 000 tonnes of concrete has been designed [12], which consists of both fixed and removable parts made using concrete blocks. The erection is scheduled in various steps. On both sides of the front door is a protected slit having an aperture of 4000 x 350 mm. This is provided for the passage of the general services, the detector services and cabling.

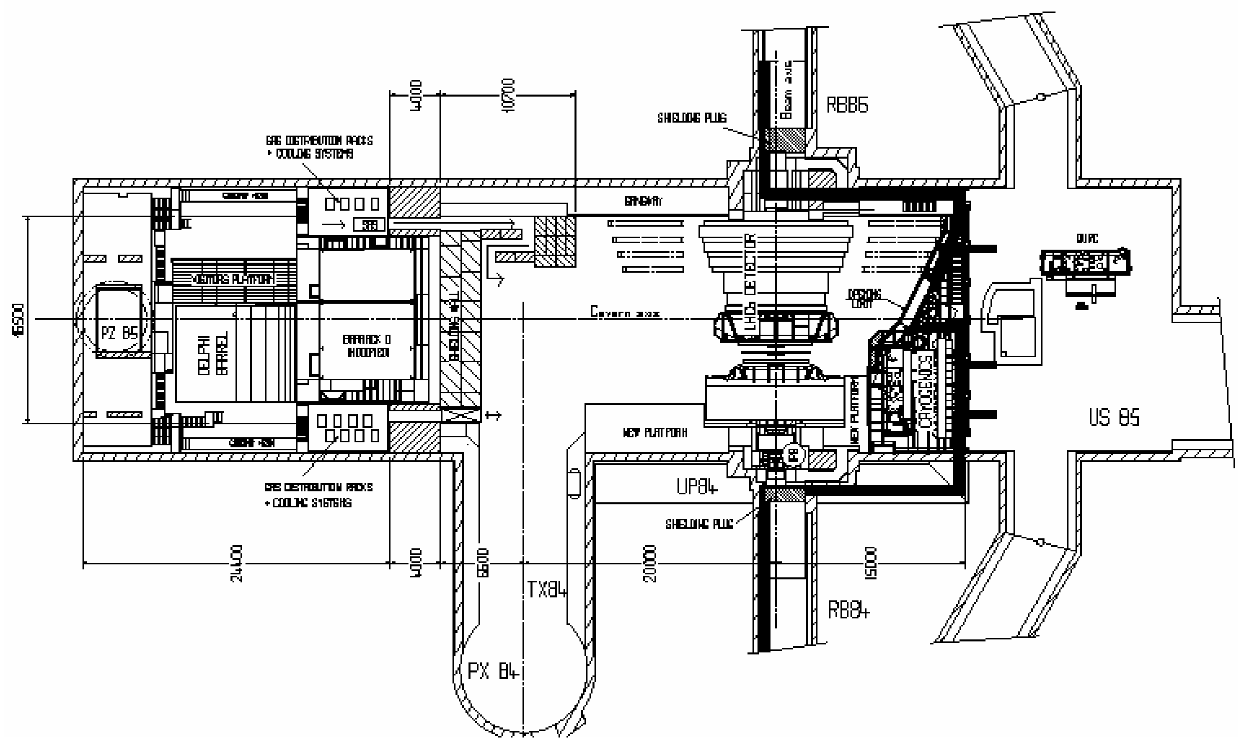

Figure 10.11: Layout of the LHCb Experiment in the UX85 cavern

Sharing space with the LHC Cryogenics

Two large cryogenic components, the QUI interconnection box and the QURCA cold box for the octant 8 are located at the end of the UX85 close to the US85 machine service area. The QURCB cold box is installed in the US85 area. The implementation in the UX85 respects the space required for the maintenance of the muon chambers. Fig. 10.12 shows the cryogenics region at the end of the UX85 area.

The space needed for accessing to the inner part of the vertex tank is Z = -2200 mm in front of IP8. The position of the last muon filter is at Z = +19900 mm. Two radiation shielding plugs made of concrete/iron blocks similar to the LEP plugs are foreseen to be installed in both RB areas [13]. A fence delimits the cryogenics region from the LHCb detector area. Appropriate exit doors are available as emergency escape routes.

10.5.3 Primary Services

The global power distribution requirement for LHCb in the UX85 cavern is about 7 MW. The warm dipole magnet requires 5 MW, the rest of detector 2 MW. The refrigeration power needed is 5 MW using de-mineralized water for cooling the magnet [14], and 2 MW using mixed and chilled water for the rest of the experiment [15].

The existing ventilation system is re-useable, however a few adaptations and modifications were required in order to have two independent air systems for the detector and the protected areas, with a slight over-pressure in the protected area [16].

10.5.4 Access & Safety

The protected area is accessible via the PZ shaft when the LHC operates. The main LHCb access checking point is located in the UX85 protected area at the entrance of the chicane which passes through the shield in order to reach the detector area for maintenance when the LHC is not in operation, such as during technical stops or regular shut-downs.

No specific safety requirements are to be mentioned except the use of a large amount of Be metal. Three segments of the vacuum beam pipe [17] are made of Be metal. The presence of large quantity of CF_4 gas in the RICH2 detector also requires appropriate safety devices to be locally installed, such as an oxygen deficiency detector in the tunnel beneath the RICH2 which would trigger an alarm in case of a serious leaks of large volumes of gas.

Figure 10.12: Picture of the QUI interconnection box in its final position

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