Chapter 5 Infrastructure consolidation

P. Burdelski, F. Dragoni, S. Grau, J-C. Guillaume, D. Jaillet, S. Mcilwraith, M. Polenghi, E. Sanchez

5.1 Civil engineering

5.1.1 Introduction

Constructed in 1963, Building 157 is 113 m long and 43 m wide at ground level. The roof is 21.8 m high at the central point above a skylight running longitudinally down its centre; it has a slope of 20% running down to the longitudinal façade summits at 15.6 m. The roof is 47.4 m wide as the longitudinal façades include wings protruding 2.2 m from a height of 7.5 m to the summits, running the entire length of the building. The longitudinal façades are made up of a variety of materials (masonry, wood agglomerate, fibro-cement, and glass, see Fig. 5-1 numbering for a detailed explanation). The end walls are made of reinforced concrete (Northwest wall) or wood agglomerate (Southeast wall).

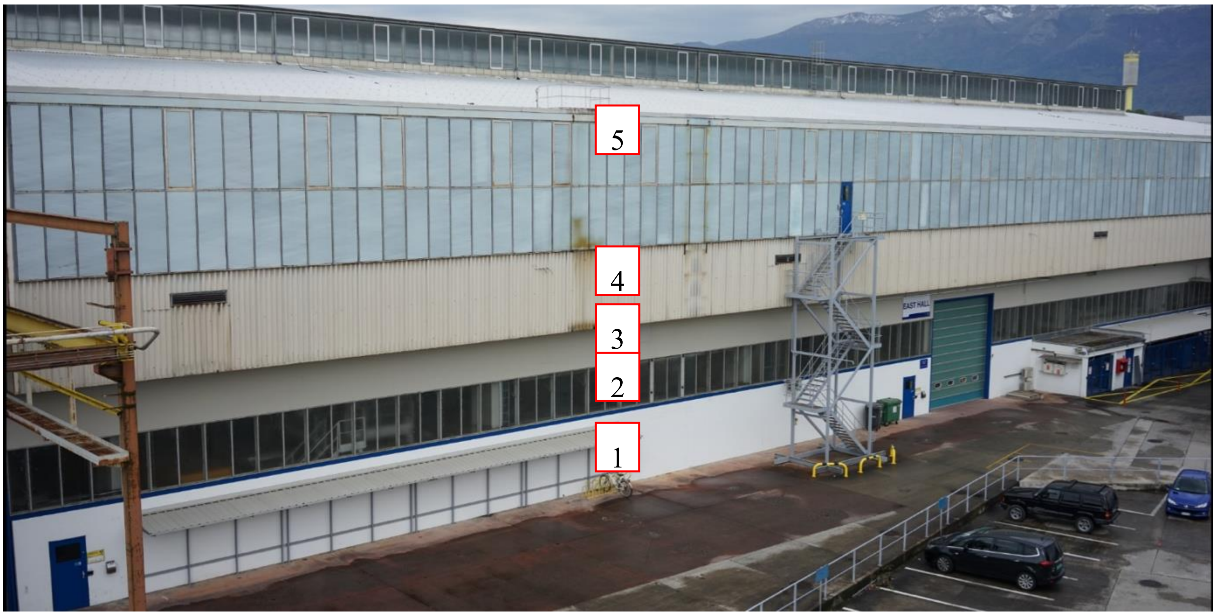

Fig. 5-1: East Hall as seen from the SMB-SE drone with material identification.

1. Masonry walls.
2. Lower windows (Northeast façade only).
3. Wood agglomerate panels (Durisol).
4. Corrugated fibro panels (forming the base and the lower part of the wing).
5. Two levels of mid-level windows.

The East Hall is now 55 years old and many facets of the building envelope are in an unacceptable state. There are dilapidated and unsafe materials forming and falling from the envelope of the building. The uninsulated envelope does not conform to current building energy-management requirements, resulting in disproportional thermal losses and hence financial losses due to heating requirements.

The envelope renovation project has two principal objectives with a number of specific objectives [1].

– ‘To improve the safety and comfort in the building by replacing the existing envelope’.

- Removing the dilapidate asbestos-containing ceiling panels.
- Removing existing poorly fixed, single-glazed windows with asbestos containing joints.
- Removing existing uninsulated fibro-cement façade panels.
- Eradicating the water infiltrations coming from the roof.

– To ensure a synergy with the consolidation of the façade of the attached Building 156 (see Fig. 5-2).

As such, the entire envelope was studied in an attempt to create a safe environment, optimizing energy savings, responding to modern building codes, and respect an aesthetic liaison with Building 156.

Fig. 5-2: Sky view of Buildings 157 and 156.

5.1.2 Solutions

5.1.2.1 Long façades

All surfaces of the long façades will be modified to improve the safety, insulation (see Table 5-1), and functionality of the building, as well as the aesthetics (see Fig. 5-3) [2].

i) The masonry walls will be insulated via the exterior face with sandwich panels.

ii) The lower windows will be replaced with better-insulated windows.

iii) The Durisol panels will be insulated via the exterior face with sandwich panels.

iv) The Eternit panels will be removed and replaced with 120 mm sandwich panels.

v) The lower part of the mid-level windows will be replaced with 120 mm sandwich panels. The upper part of these windows will be replaced with translucent polycarbonate panels equipped with heat-stop film on the exterior face. This will allow the passage of non-direct sunlight whilst reducing the impact of extreme heat during the summer time and eliminating direct sunlight from the building.

Table 5-1: Comparison between existing and new materials thermal transmittance values for long façades.

Existing material	**Existing U [W/m^{2}K]**	**New material**	**New U [W/m^{2}K]**
Masonry walls	2	Masonry walls + 100 mm sandwich panels	0.17
Lower windows	5	New lower windows	1
Durisol panels	1	Durisol panels + 100 mm sandwich panels	0.16
Eternit	3	120 mm sandwich panels	0.19
Mid-level windows	5	120 mm sandwich panels/polycarbonate panels	0.19/1.1

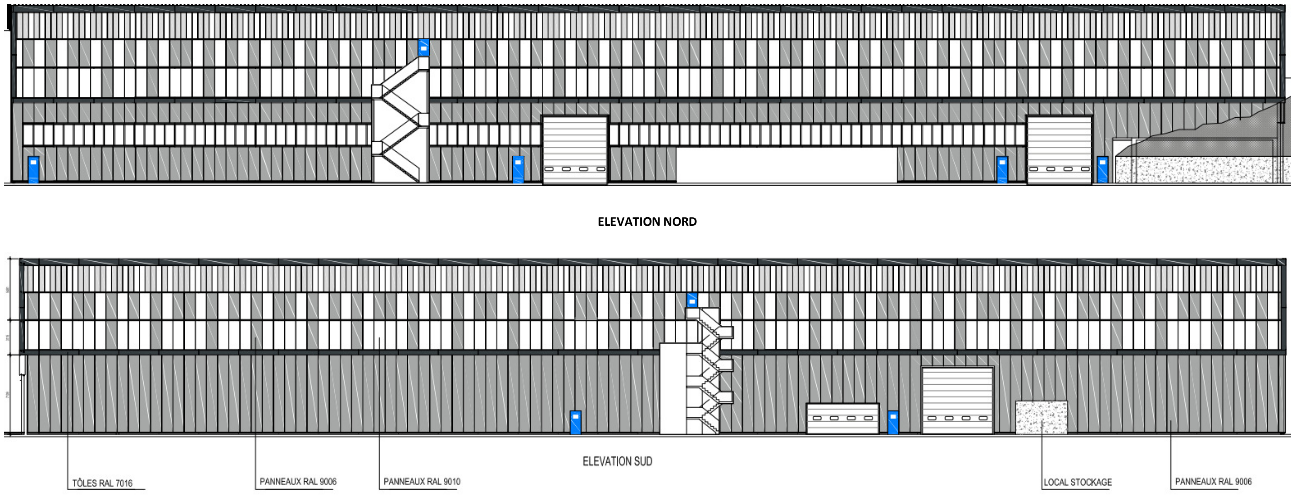

Fig. 5-3: Future Northeast and Southwest façade materials.

5.1.2.2 Roof and ceiling

Many solutions were considered for the replacement of the ceiling/roof system, however, the optimal solution chosen is the removal of the asbestos containing ceiling panels and insulation and the dismantling of the roof sheet. These will be replaced by a single system of insulated sandwich panels placed above the roof structure. Furthermore, the existing sky lantern will be demolished and replaced with a classic gable roof (see Fig. 5-4), as is already the case for the two extremities of the building. This demolition allows for a reduction of a lost heating volume at the top of the building, it also reduces a number of thermal bridges given the number of different materials constituting the sky lantern.

Due to the removal of the current building smoke ventilation opening windows, classic ventilation traps will be added to the roof as illustrated in Fig. 5-5. This allows the upgrade to the correct extraction surface to improve the safety of the building.

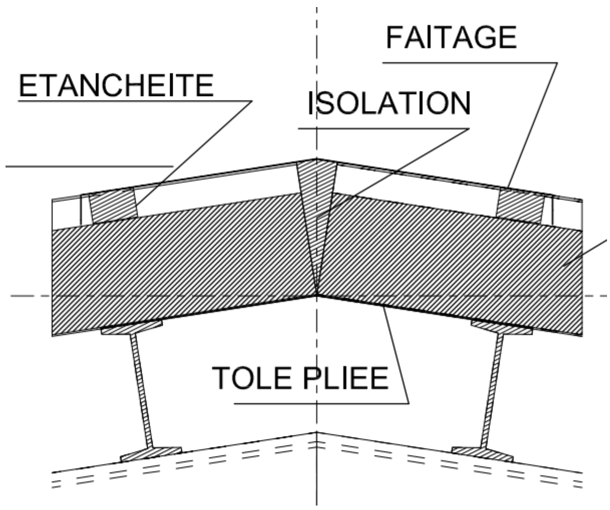

Fig. 5-4: New gable roof peak design.

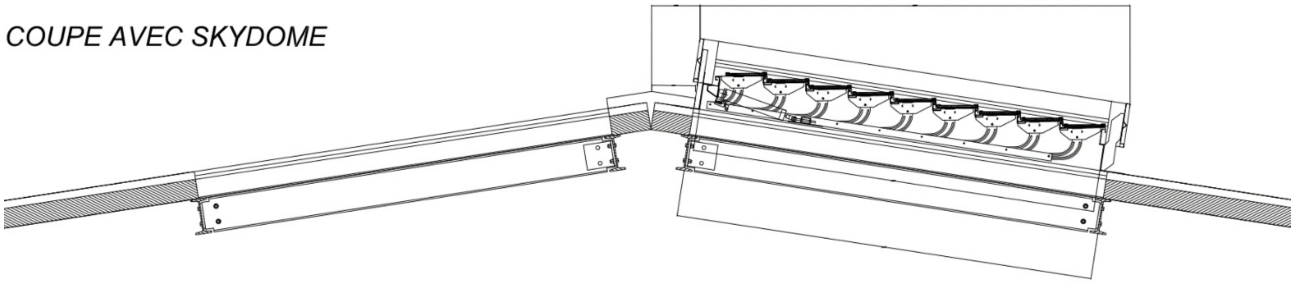

Fig. 5-5: New smoke ventilation trap.

5.1.2.3 End walls

The Northwest end wall will be insulated using 100 mm sandwich panels on the exterior face of the existing concrete (Fig. 5-6). This will only be carried out on the area of the wall that is above the fill level of the PS as the underground portion of the façade is not susceptible to significant heat losses.

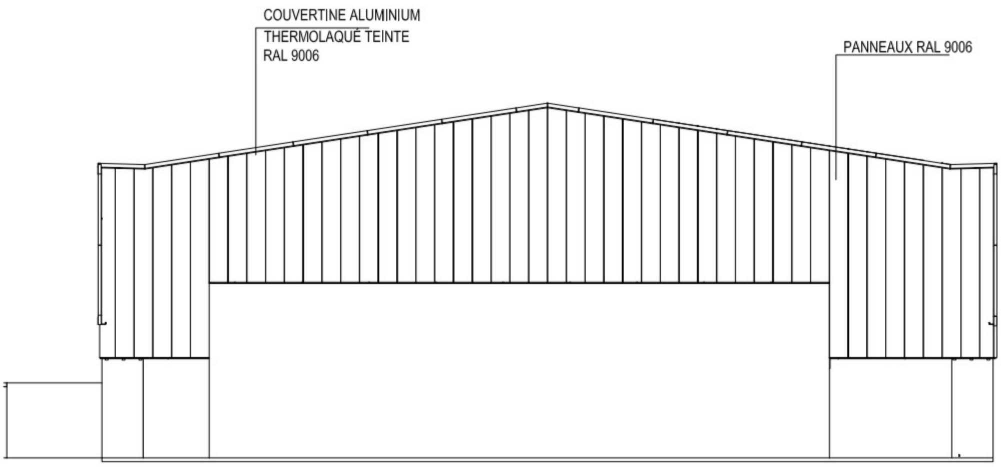

Fig. 5-6: Northwest end wall.

The Southeast wall is made of wood agglomerate (Durisol) panels and is insulated using 100 mm sandwich panels uniquely where it is exposed to the exterior. The large rectangular opening visible in Fig. 5-7 represents the portion of the wall giving to the Building 156 hangar.

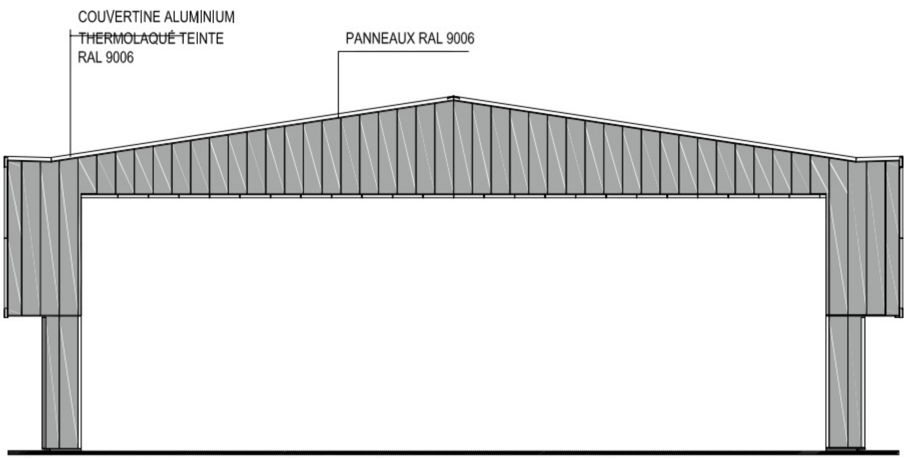

Fig. 5-7: Southeast end wall.

5.1.3 Conclusions

The new envelope provides a significant reduction in building energy losses. The simplified calculation shows that there is an 89% reduction in energy losses through the building envelope.

This new envelope equally provides a much safer and more functional work environment whilst at the same time making a drastic aesthetic improvement to the building (see Fig. 5-8).

Fig. 5-8: Architects 3D rendering of future upper Northeast façade.

5.2 Cooling plant and circuits

5.2.1 Scope

The scope of this project is to consolidate the demineralized water-cooling systems for the East Area magnets and power converters as follows (Fig. 5-9 summarizes the solution):

i) provide demineralized water cooling to magnets in Building 157 mixed and secondary zones;

ii) provide demineralized water cooling to equipment test lines employed by CERN High Energy AcceleRator Mixed field facility/proton IRRADiation facility (CHARM/IRRAD) users in Building 157;

iii) provide demineralized water cooling to power converters in Building 355 hall;

iv) provide demineralized water cooling to power converters in Building 251;

v) provide a dedicated demineralized-water cooling circuit to magnets inside Building 157 primary zone bunkers, PS, and to those CHARM/IRRAD equipment test lines that are installed inside CHARM bunker.

5.2.2 User's requirements

The requirements for magnets, CHARM/IRRAD equipment test lines, and power converters are summarized in Table 5-2 and in Ref. [3].

No specific requirements are made for pH and O_2 values. The demineralized water circuits shall have sampling points for water analysis purposes.

The demineralized water-cooling system shall have an n+1 redundancy on pumps. No connection to the secured network is required.

Table 5-2: East Area demineralized water: user requirements.

Cooling requirements	**Unit**	**Magnets circuit – mixed and secondary zones**	**Magnets circuit – primary zones + PS**	**B355 Power converters circuits**	**B251 Power converters circuits**	**CHARM/ IRRAD Equipment lines (External)**	**CHARM/ IRRAD Equipment lines (R-050)**
Nominal supply temperature	[°C]	27	30	27	27	27	30
Maximum supply temperature	[°C]	28	31	28	28	28	31
Maximum cooling power of the system – cycling operation	[kW]	142	150	120	398	14	7
Maximum flow rate	[l/min] [m^3/h]	961 58	561 34	467 28	1 764 106	20 1.2	10 0.6
Pressure rating		PN25	PN25	PN16	PN16	PN10	PN10
Water conductivity	[µS/cm]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

5.2.3 Technical solution

The cooling of magnets, CHARM/IRRAD equipment test lines, and power converters is overseen by 2 cooling stations and the associated distribution networks as follows (see Ref. [4]).

– **Demineralized water station – Building 355 – FDED-00355 -** that will supply demineralized water to magnets in Building 157 mixed and secondary areas, CHARM/IRRAD equipment test lines in Building 157 hall and power converter in Building 251 main hall. It will also act as primary for the demineralized water skid FDED-00251 (Building 157).

– **Demineralized water skid – Building 157 – FDED-00251 -** that will supply demineralized water to the magnets in Building 157 primary zone bunkers and Building 352 and to the CHARM/IRRAD equipment test line installed in CHARM bunker 157/R-050.

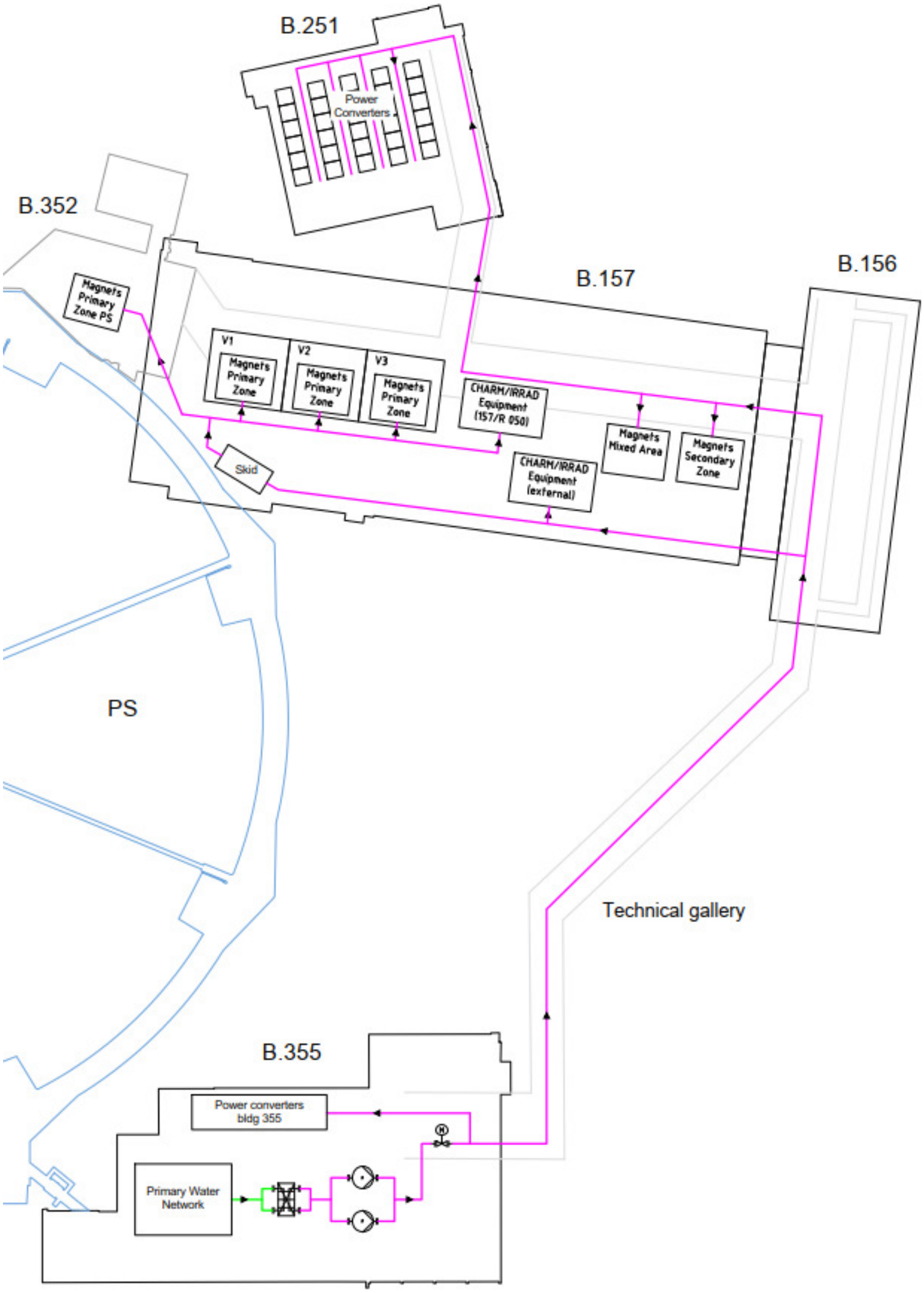

Fig. 5-9: Synoptic of the East Area demineralized water distribution.

5.2.3.1 Demineralized water distribution network

Figure 5-9 shows the synoptic of the demineralized water distribution network. All existing piping of correct nominal diameter (ND) size and in good status will be preserved and reused, the remaining will be replaced. Redundant pipework will be removed.

Pipework will be routed in technical galleries and then supply demineralized water to:

– **magnets**: pipework will be installed along the various beamlines arriving in close proximity to each magnet in order to minimize pressure drops in flexible piping. Pressure reducing valves will be installed on main branches after having supplied demineralized water to those magnets with the highest pressure drop;

– **power converters**: the piping coming from the cooling station will split in one DN100 and one DN125 branches that will branch off piping of sizes ranging from DN40 to DN50 to reach each cluster of power converters. Pressure reducing valves will be installed on the main branches;

– **CHARM/IRRAD equipment test lines**: the existing distribution to CHARM/IRRAD equipment test lines external to the shielding block will be kept. The current test lines have pressure reducing valves from 25 to 12 bar; as the new demineralized station, Building 355 will supply demineralized water with a pressure of up to 14 bar; new pressure reducing valves will replace the existing ones. The final distribution to CHARM/IRRAD equipment test line inside CHARM bunker will branch off the pipework supplying demineralized water to the magnets in the V3 bunker.

5.3 Buildings 157 and 251 ventilation

5.3.1 Building 157 ventilation

5.3.1.1 Scope

The scope of this project is to consolidate the heating, ventilation, and air conditioning (HVAC) system of Building 157 hall to provide heating during winter and ventilation during summer.

5.3.1.2 User requirements

The ventilation requirements for the Building 157 hall are listed in Table 5-3 and in Ref. [5]. No humidity regulation is needed. All fresh and recirculated air will be filtered. Redundancy of any functionality of the HVAC systems is not required during normal operation or in the case of a power cut or fault in the electrical power supply systems.

Table 5-3: Building 157 hall: ventilation requirements

Temperature range [°C]	Min fresh air rate per person [m3/h]	Max occupancy [persons]
17–29	45	100

5.3.1.3 Technical solution

The HVAC system of B157, which is illustrated in Fig. 5-10, will have:

i) **Eight air-handling units (AHUs) –** four on the North side with a nominal flow rate of 12 000 m^3/h and four on the South side with a nominal flow rate of 9 000 m^3/h. Each unit will be equipped with heating coils for winter temperature control and summer ventilation. They will have fresh air intake that will provide minimum 1 000 m^3/h each.

ii) **Eighteen destratification fans –** with a nominal flow rate of 9 000 m^3/h and 5 300 m^3/h installed on roof supporting steelwork. These fans will help de-stratify the temperature gradient associated with convective heating.

iii) **Two air curtains –** to prevent a cold draft from entering the building during operation of the two stacking doors on North façade.

iv) **Hot water station and distribution circuits** to feed the heating coils of the AHUs.

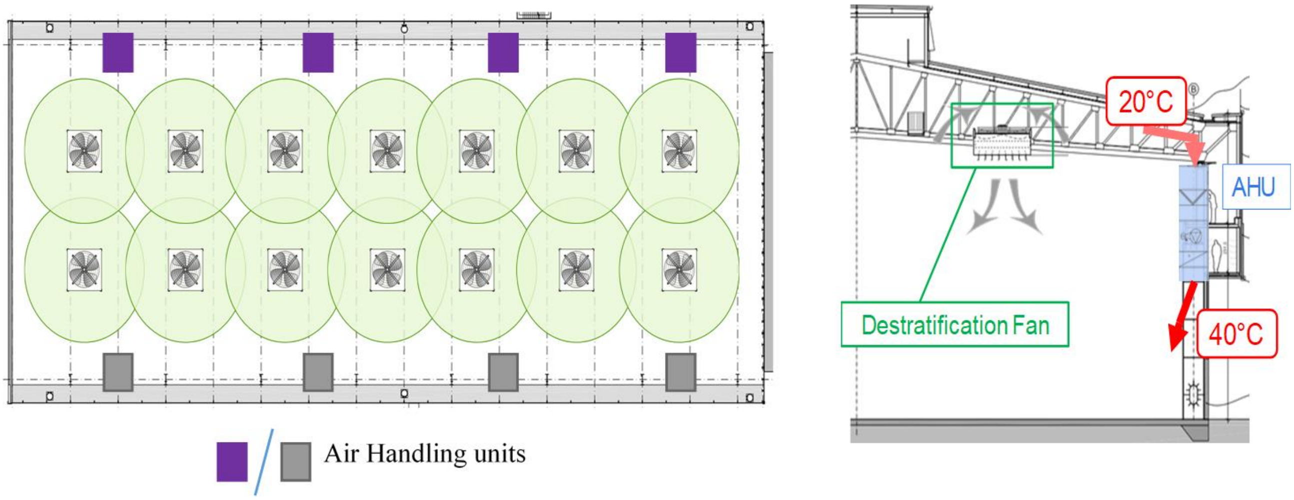

Fig. 5-10: Left: top view of Building 157 with the position ventilation systems, right: vertical cut of Building 157.

The air handling units will have a common mixing chamber where fresh air is mixed with recirculated air. This will normally occur in summer when the units will work with full fresh air during nights and with recirculation during hot periods of the day.

Air will be supplied by new ductwork installed along the building walls. The ducts will have a single wall construction and have grilles to ensure uniform distribution in the building. The return air intake will be on top of each air handling unit.

5.3.1.4 Safety aspects

In case of fire detection and power failure, all AHUs and destratification fans will automatically stop and all dampers will close.

5.3.2 Building 251 ventilation

5.3.2.1 Scope

The scope of this project is to provide HVAC systems to the following.

– **Power converter hall (R-007) –** to ensure temperatures inside power converters are within their operating limits and to prevent frost damage in pipework installed in false floor.

– **Plant room (R-005)** – to provide heating during winter periods to avoid frost damage.

5.3.2.2 User's requirements

The air-cooling requirements for power converters are as listed in Table 5-4 and in Ref. [5]. The minimum temperature inside power converters is 15°C and maximum temperature is 33°C immediately above the capacitors and of 38°C above the capacitors. No condensation will occur.

Ventilation air will be filtered. Redundancy of any functionality of the HVAC system for power converters is not required during standard operation as well as maintaining specific functionalities in degraded mode or in case of power cut or fault in the electrical power supply systems.

Table 5-4: Building 251 power converters: air cooling requirements.

Power converter type	Number of installed power converters	Dissipated unit power via air cooling [kW]	Total dissipated power via air cooling [kW]
SIRIUS S	19	1.4	26.6
SIRIUS 2P	25 + 1 (spare)	2.6	65.0
SIRIUS 4P	9	4.9	44.1
SIRIUS 4P+	8 + 2 (spare)	5.9	47.2
TOTAL			182.9 kW

5.3.2.3 Technical solution

The HVAC system of Building 251 will have the following.

– **Two air handling units –** with a nominal flow rate of 31 000 m^3/h each and heating and cooling coils for temperature control and frost prevention of power converters hall 251/R-007.

– **Two heating units** – with a nominal flow rate of 10 000 m3/h with heating to coil to provide heating to plant room 251/R-005.

– **Chilled water and superheated water distribution circuits** to feed the air handling and heating units.

The air handling units will have a common mixing chamber where fresh air is mixed with recirculated air. This will normally occur in winter and in summer, when the recirculated air is cooler than external air. In summer, when recirculated air is hotter than the external air, the units will work with full fresh air. Air will be blown by two air handling units into the plenum between the building floor and false floor and it will flow through the power converters before being either recirculated or exhausted, as illustrated in Fig. 5-11. Motorized dampers installed at a high level in the power converter hall will serve as air exhausts.

Air ducts will be of double wall construction for air supply above the false floor and single wall construction inside the false floor. Air ducts will have grilles to ensure uniform distribution amongst power converters. Heating units will ensure minimum temperatures are maintained in the plant room and that there will be no frost.

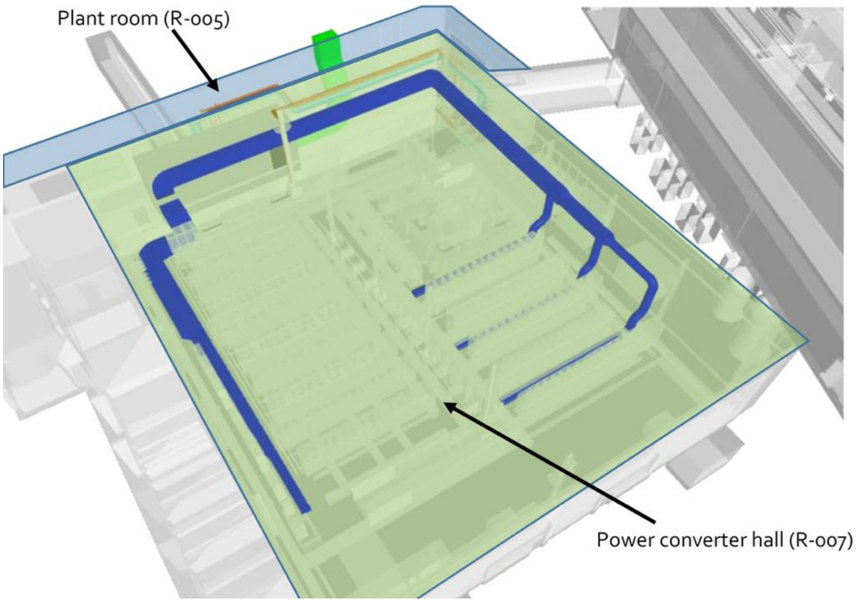

Fig. 5-11: View of the Building 251 and the position of the ducts (in blue) in the power converter hall.

5.3.3 *Safety aspects*

In case of fire detection and power failure, the HVAC system of Building 251 will automatically stop and all dampers will close.

5.4 Primary area ventilation

5.4.1 *Scope of the project*

The scope of this project is to provide HVAC systems to:

– **Primary zone bunkers –** to contribute to ensuring a dynamic confinement of the bunkers (Fig. 5-12) during operation, to provide the flush of the bunkers before access, to cope with the heat load of the magnets, and to guarantee the required temperature stability.

– **Mixed area –** ensuring fresh air supply during access to the area.

Fig. 5-12: Location of the primary zone bunkers (V1, V2, and V3) and the mixed area.

5.4.2 *User's requirements*

The HVAC systems shall operate in three modes (see Refs. [6] and [7]).

i) Beam mode – when beamlines and magnets can receive the beam.

ii) Flush mode – when beamlines and magnets will not be receiving the beam and activated air is flushed out of the primary zone bunkers; no flush is required for mixed area.

iii) Access mode – when access to primary zone bunkers is possible.

The HVAC system of the primary zone bunkers will ensure that temperatures are kept to 22 ±3°C inside the bunkers in all modes of operation. Recirculated air and exhausted air will be filtered with F9 filters. No humidity control is required.

This HVAC system will ensure dynamic confinement of the primary zone bunkers during the beam and flush mode so that the bunkers are in underpressure with respect to adjacent areas (with an air permeability rate of 10 $m^3 h^{-1} m^{-2}$ at 50 Pa the pressure difference should be –20 Pa). An interlock between the HVAC system of the primary zone and the access system (see Section 5.8) is required to prevent access during beam and flush modes.

The HVAC system of the mixed area will ensure the minimum supply of fresh air to the mixed area premises for safety reasons. No interlock with the access system is required. Redundancy of the ventilation system and connection to the secured network are not required.

5.4.3 Technical solution

The HVAC system of the primary zone bunkers will have (Fig. 5-13):

i) **One air handling unit – UARJ-00043 –** with a nominal flow rate of 5 400 m3/h.

ii) **One extraction unit – UAEJ-00037 –** with a nominal flow rate of 10 200 m3/h.

iii) **Airtight filter casing – UAEF-00017 and UAEF-00018 –** with F9/ePM1 80% filters that will filter the recirculated and exhausted air, respectively.

iv) **Air cooled chiller – FCK-00182 –** with chilled water production range 12–18°C.

Air ductwork will be of double wall construction for air supply and single wall construction for air return, fresh air, and exhaust air. Routes, diameters, and additional information can be found in Ref. [7].

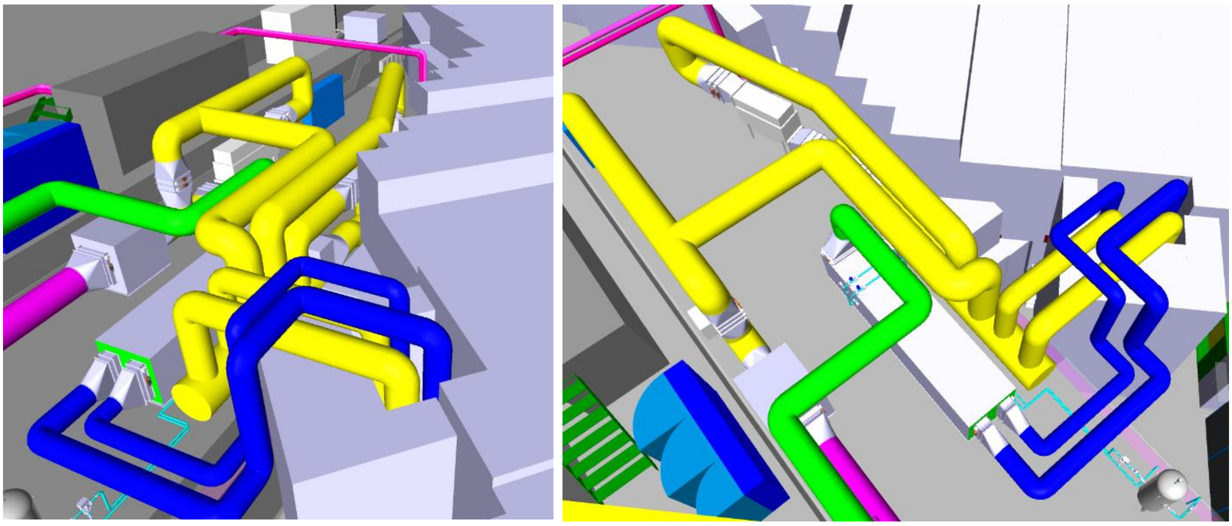

Fig. 5-13: Three-dimensional integration of the air handling units and the ducts for the primary area.

The ventilation system of the mixed area will have a supply fan that will supply air from the hall to the mixed area bunker during flush and access modes. It will be off during beam mode.

In case of fire detection, the ventilation systems for the primary zone and mixed area bunkers will automatically stop and all dampers will close as the beam and the heat loads will be switched off.

In case of power failure, the ventilation system for the primary zone and mixed area bunkers will stop.

To cope with radioprotection requirements, the air ducts will be routed through a chicane made of concrete blocks, as shown in Fig. 5-13.

5.5 Electrical distribution

5.5.1 Introduction

This section describes the consolidation of the electrical infrastructure [5] in the East Hall (Building 157) and in electrical substations ME11 (Building 251), ME8 (Building 252), and ME22 (Building 263).

In the existing network, seven 18/0.4 kV transformers supply the power converters and one supplies, from Building 252, the general services of Building 157 and other surrounding buildings. Two special transformers, which were already removed before the consolidation, supplied other converters.

The future design, based on the inputs received from the users, allows an important optimization of the installed power, with an improvement in terms of operation and maintenance.

5.5.2 Future network topology

Figure 5-14 illustrates the simplified future single line diagram: two transformers (EMT105*11 and EMT104*11) will supply the power converters in Building 251, one transformer (EMT103*11) the general services network of the area, and one transformer (EMT106*EH) the experimental areas in Building 157.

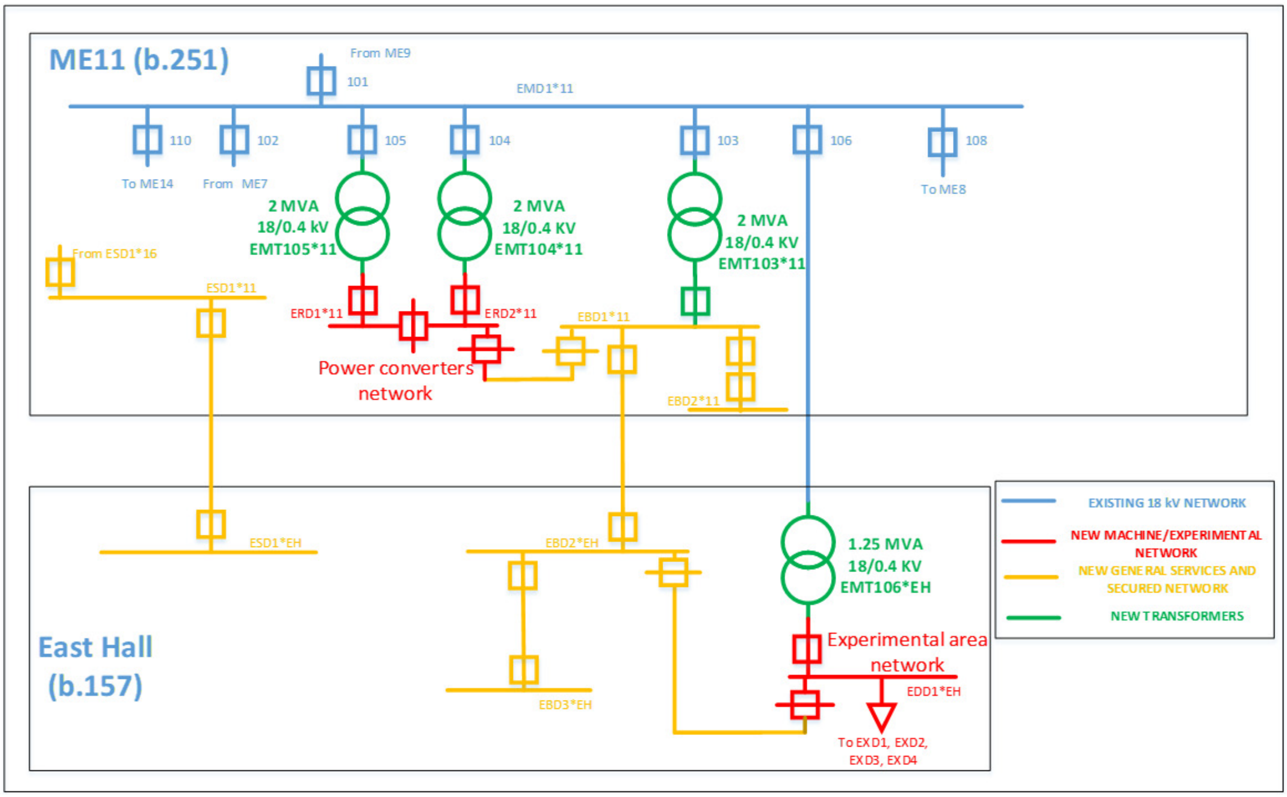

Fig. 5-14: Future single line diagram.

5.6 DC circuits

5.6.1 Existing wiring principle

The current wiring principle gives a lot of flexibility to the direct current (DC) circuits in the East Area. All the power converters are connected to a line selector in Building 251. This allows the operation team to choose to which terminal boxes (TBs) the DC power should be sent to (Fig. 5-15). Ultimately, the magnets can be connected to any of the terminal boxes in Building 157.

Fig. 5-15: Left: line selector in Building 251, right: terminal boxes in the technical gallery under Building 157.

5.6.2 Requirements

The advertised current intensities implemented by the converters are 200, 400, and 800 A [8]. For waste reduction reasons, it was determined if the existing cables could be re-used. The line selector (in light red in Fig. 5-16) and the TBs are in a very old state and shall be dismantled, meaning that the magnets will be directly connected to the power converters. DC circuits to Building 263 will be fully dismantled (in red in Fig. 5-16). Only the two extremities of the cables will be replaced (in yellow in Fig. 5-16).

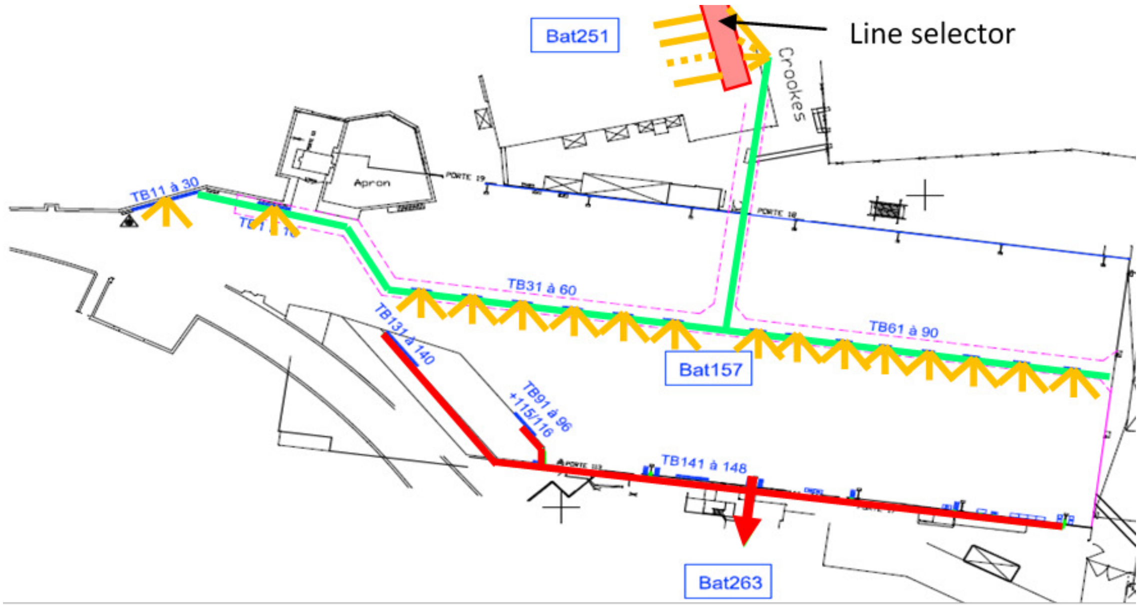

Fig. 5-16: DC cable wiring principle with the cables to be kept (green), replaced (yellow), and removed (red).

5.6.3 Technical solution

After study, the number of cables per circuit was determined as follows:

- 200 A: 1 × 240 mm^2 aluminium per polarity giving 0.125 Ω/km at 20°C.
- 400 A: 2 × 240 mm^2 aluminium per polarity giving 0.0625 Ω/km at 20°C.
- 800 A: 3 × 240 mm^2 aluminium per polarity giving 0.0416 Ω/km at 20°C.

The voltage drop induced by the existing cables is then compatible with the future power converters.

Table 5-5 shows the total quantity of cables and lengths (new cables amount to a total of 14 km) taken into consideration.

Table 5-5: Quantity of DC cables.

Beamline	**Quantity of cables**	**Total Length (m)**	**Total length re-used (m)**
F61	38	7 658	5 172
F62	14	2 852	1 792
F63	18	2 838	1 710
T08	42	5 412	3 186
T09	54	6 158	3 502
T10	48	5 770	3 198
T11	26	3 712	2 182
Total	240	34 400	20 742

5.6.4 Implementation

In the new layout, the distribution of magnets and converters is completely different, so it is not possible to keep existing cables at their current locations. The recoverable part is located between the entrance of Building 251 and the civil engineering openings of hall 157 and up to the TBs located in Building 352. At the interfaces, each 1 × 240 mm^2 aluminium cable will be sleeved with a single-pole 1 × 150 mm^2 copper cable [9].

5.7 Signal cables

Current beam control systems were implemented some twenty years ago. The technicality of some of them having evolved and the new configuration of the equipment of the beams being different, it was decided to:

i) Remove signal cables from obsolete systems.

ii) Remove signal cables from systems whose equipment is no longer in the same place.

iii) Install new cables for new systems as well as those whose equipment has changed place.

5.7.1 Removal of signal cables

Careful identification has been performed [10] to quantify and identify the cables to be removed [11]: about 285 km of cables will be removed in four different buildings (157, 251, 352, and gallery 817).

5.7.2 Installation of new cables

All the cables to be pulled are summarized in Table 5-6.

Table 5-6: Details of new cables to be installed for East Hall Renovation project.

System	Quantity of cables
Machine Interlock	120
Beam instrumentation	150
Collimators control	18
Radiation monitoring	60
Targets control	36
Vacuum system	32
Beam stoppers	42
Access system	44
Gas detection	48
Controls for CHARM	27
Power converters control	67
Gas systems	37

5.7.3 Cable tray infrastructure

The cable trays installed in Building 251 and along the beamlines in the hall of Building 157 will be removed and replaced with new ones according to the new configuration of beamlines and concrete blocks. The removal corresponds to a total of 500 m.

Hall infrastructure paths as well as those existing in the gallery are retained and re-used.

5.8 Personnel protection systems

5.8.1 Introduction

This section describes the modifications required by the East Area Renovation Project to the existing personnel protection systems (PPS) regulating the access of personnel to the East Area primary and experimental zones. It presents the users' technical requirements and the system principles. The renovation includes the modification of two type of access systems:

– Access systems for primary beam areas:

Access to the East Area primary beamlines is managed by two independent areas, named EA1 and EA2, each managed by a PPS. Modification of the PPS of EA1 and PPS of EA2 IRRAD-CHARM concern the sectorization, the safety related elements, and the external safety conditions.

– Access system for secondary beam area and Building 157 control rooms, buffer zones, and storage rooms:

Access to each of the East Area experimental areas is managed by a PPE (personnel protection entry). The following modifications will be implemented:

– T09, T10, T11: PPEs re-located.

– New PPE for new zone T09-10.

– New function: EA experimental areas remote operation from the CERN CCC for veto management and chain tests.

– Access control on doors of control rooms, buffer zones, and storages located inside Building 157: re-located or new.

5.8.2 PS complex PPS principles and role

During Long Shutdown 1 (LS1), the PS Accelerator Complex access systems were renovated to cope with new operational needs and regulations and standards applicable for the 'Installation Nucléaire de Base (INB)'.

Each zone is managed by a dedicated PPS and can be divided into different access sectors (equipped with various elements such as sector doors, end-of-zone doors, etc.). The access sectors are particularly important to organize the patrol of the machine and to minimize the radiation exposure by means of a radiation veto handled by the RP responsible person. Access to the zone is done via an *access point* composed of a personnel access device (PAD) and a material access device (MAD). Adjacent zones are separated through inter-machine doors. The closure of the external envelope of each zone is ensured by end-zone doors which are normally used only for evacuation in case of emergency.

The East Beam primary area is divided into two interlocked zones, EA1 for the primary beamline area and EA2 for IRRAD-CHARM primary areas.

The main role of the PPS is to ensure that there is no danger (radiological hazard or other risks identified in the APR [15][16] such as activated air) during personnel access to the zone, and that no personnel are present inside the zone during BEAM operation.

The PS PPS is composed of two complementary subsystems, the PS access control system (PACS) and the PS access safety system (PASS). The PACS ensures a physical barrier and controls access by means of automatic or remotely controlled security portals and access devices for personnel and material. Access points regulate personnel access to supervised and controlled machine areas, it ensures users identification, biometric authentication, and regulates at the highest safety level (single person check, audio, video, etc.) the access according to the operation modes managed remotely by the CCC.

The PASS ensures that at any time and in every operation mode of the various machines, the PS Complex is safe for the machine users by interlocking Access or Beam 'Important Element for Safety (EIS)' [14]. In Access mode, all the EIS beams are maintained in a safe state. In Beam mode, any intrusion within the PS Complex will immediately interlock the necessary EIS beam, stopping the beam operation to protect personnel from exposure to radiation hazards.

Each beam zone has its own independent access conditions. The absence of a beam in each independent beam zone is guaranteed by at least two beam safety elements, with at least one passive element (e.g. a moveable stopper) and one active element (e.g. magnetic power converter interlock).

The operation modes of the PS PPS are: Access, Ready for Access/ Ready for Beam (RFA/RFB), and Beam.

In ACCESS mode, safety vetoes are applied to all the EIS-beam/EIS-machine and EIS-external elements. Safety vetoes are removed from the EIS-access depending on the inter-locked zone safety conditions (radiation level, ventilation). In RFA/RFB mode, safety vetoes are applied to all the EIS-access and EIS-beam/EIS-machine elements. It is an intermediate mode. In BEAM mode, safety vetoes are applied to all the EIS-access elements, safety vetoes are removed from all the EIS-beam/EIS-machine/EIS-external elements. BEAM operations are allowed in the inter-locked zones.

5.8.3 Requirements for the PPS of EA1 and EA2 primary beam zones

The requirements for the PPS of the EA Primary zones EA1 and EA2 concern the following elements:

i) Access sectorization.

ii) EIS-beam important safety elements of the machine against radiation exposure hazard.

iii) External safety conditions associated with the new EA ventilation system.

5.8.3.1 New access sectorization for EA1 and EA2

The new EA1 beam layout aims at reducing the exposure to radiation of the personnel. In the new layout, the EA1 beam area is divided into a ‘primary area’ and ‘mixed area’, and the current single access sector is divided into three sectors: one for the mixed area (S1), giving access to the EA primary zone via the Access Point, and two sectors for the ‘primary area’ (S2, S3). Additionally, a corridor is created by opening the shielding blocks, giving direct access from EA1 to the blind sector area (accessible only through IRRAD before LS2) and therefore also to the EA2 external envelope. EA1 and EA2 are now connected with an ‘inter-zone door’ which allows passage in case of emergency (see Fig. 5-17 and Fig. 5-18).

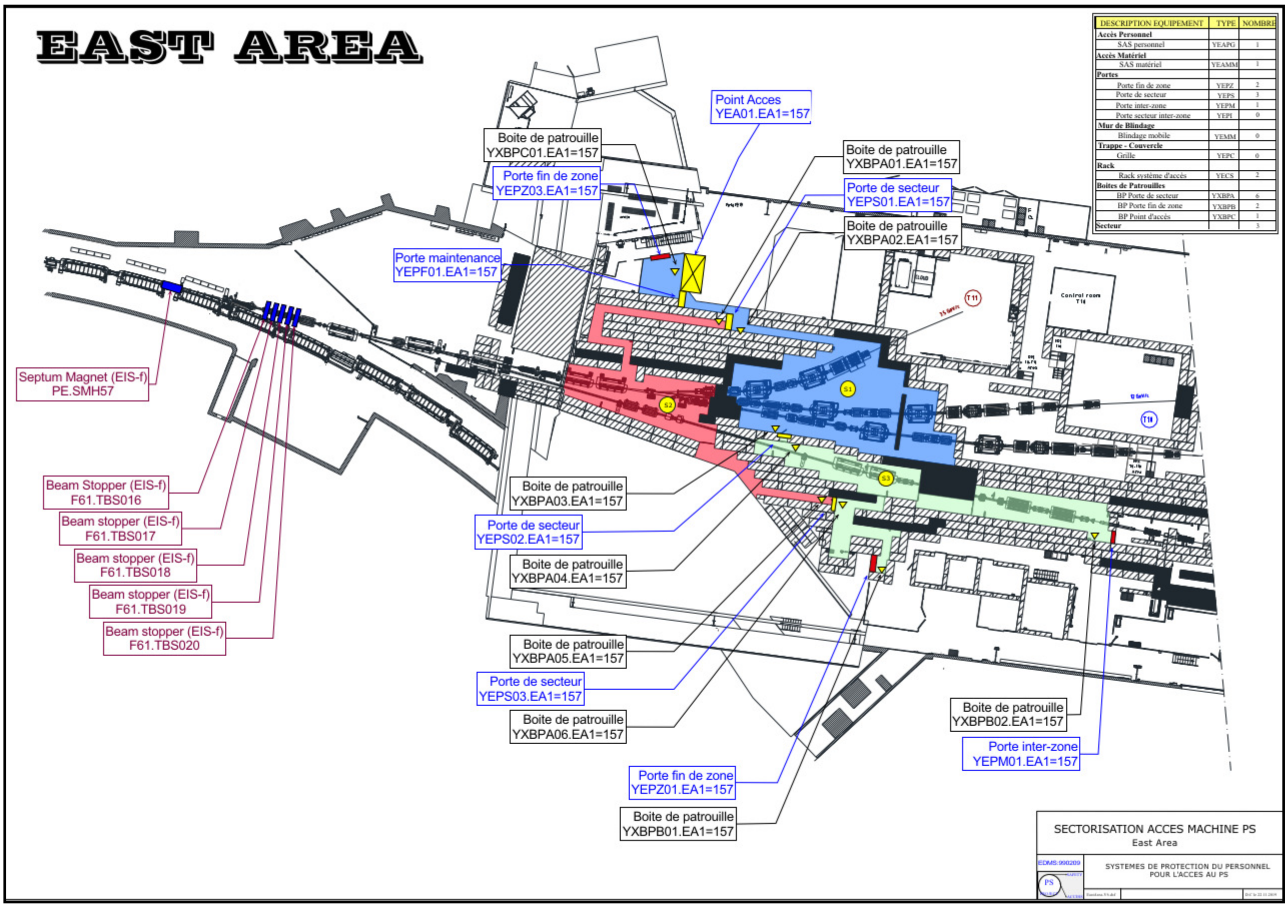

Fig. 5-17: Future access sectorization of the EA1 East Area primary beam zone.

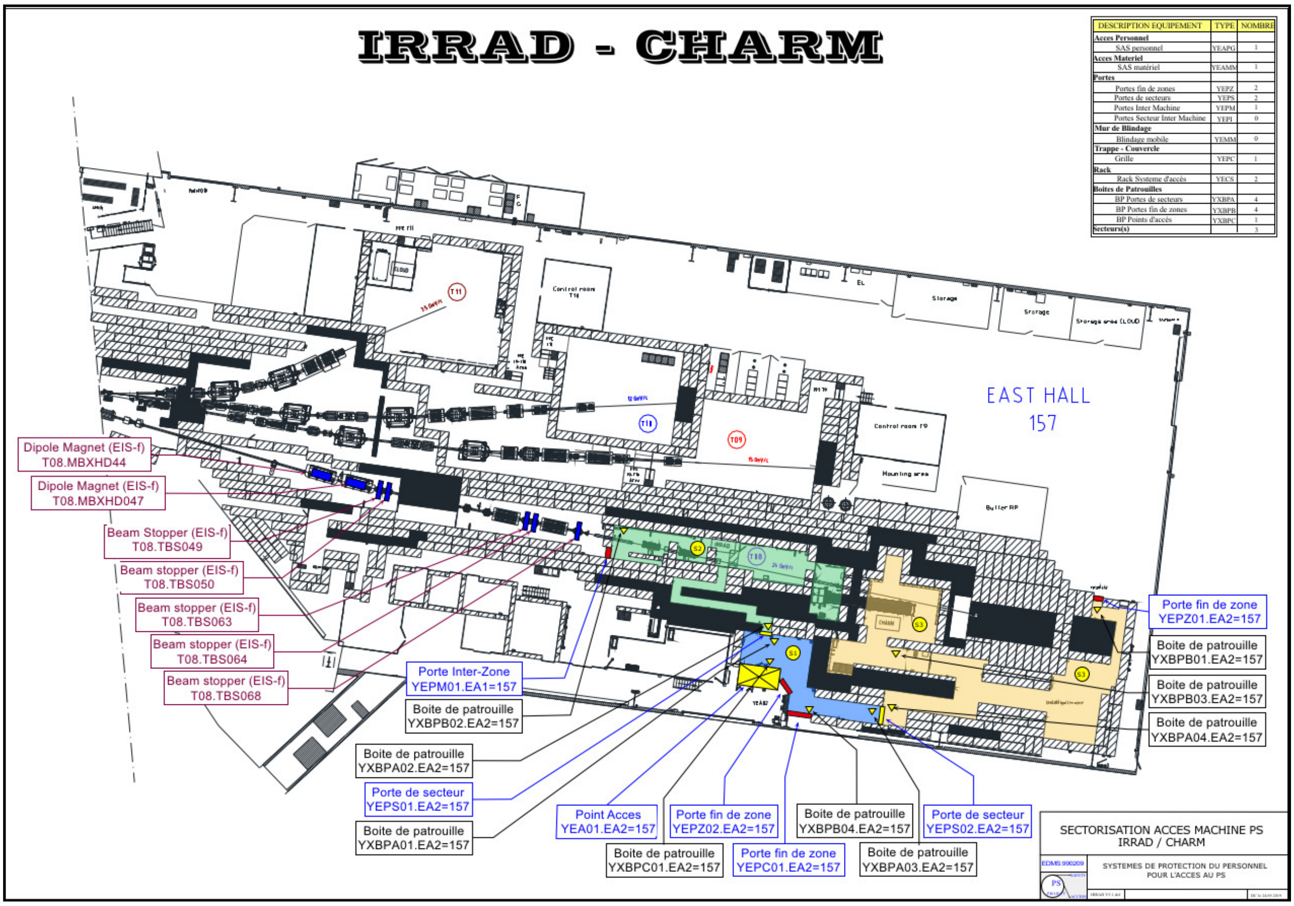

Fig. 5-18: Future access sectorization of the EA2 East Area primary beam zone.

5.8.4 Implementation of requirements for the EA1 and EA2 PPS

The EAR requirements do not question the current PS Complex PPS architecture, equipment types, and functionalities of the EA1 and EA2 PPS, which are described in the technical specifications in Ref. [23].

The architecture of the PS Complex and Experimental Area PPSs is presented in Fig. 5-19, and is composed of the following four levels, each ensuring a set of functions:

i) Operation and supervision.

ii) Central computing and safety infrastructure.

iii) Zone safety controller.

iv) Zone equipment.

Functions iii) and iv) exist specifically for each PS interlocked zone (safety chain). Two independent and redundant interlocked paths, a programmable logic controller (PLC), and a hardwired loop, ensure the PPS safety interlocks.

The PS PPSs central computing and safety infrastructure is located in Building 271. The EA1 and EA2 EIS important safety elements (access, beam, external) signals are cabled individually to their specific safety chain controller racks located in Building 271.

Due to the EAR project during LS2, all of the PPS EA1 installation located in Building 157 will be dismantled and re-installed according to the EAR requirements [17]. As presented in Section 5.8.3.1, the PPS EA2 is only slightly modified, and EAR works do not require dismantling of any PPS EA2 elements.

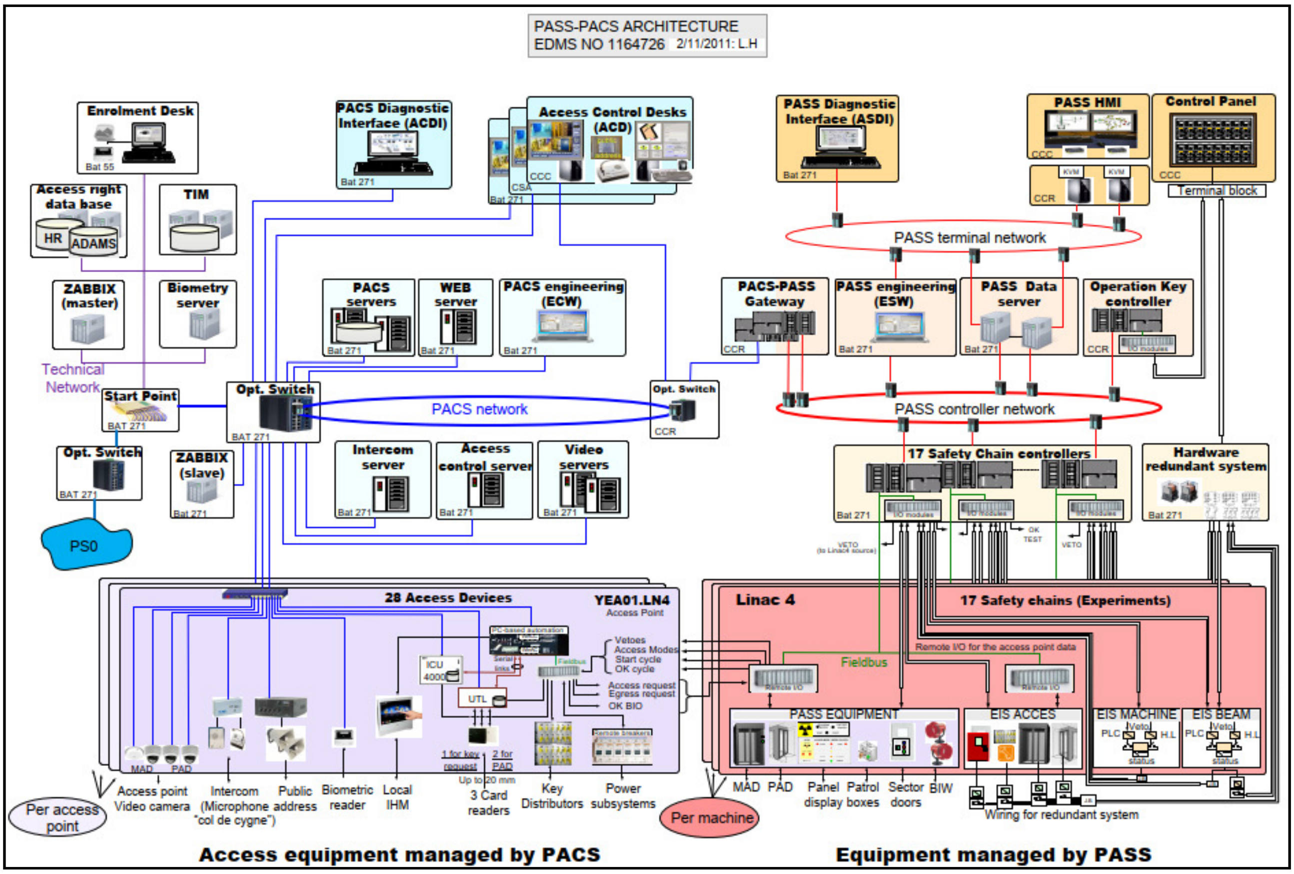

Fig. 5-19: PS Complex personnel protection system architecture.

5.8.5 Requirements for the EA experimental areas access safety systems

5.8.5.1 Scope of the renovation

An access control and safety system is currently operational in the three experimental areas (T09, T10, and T11). It ensures safe access and beam in those three independent experimental areas. Access to an experimental area is done via an access control door, known as PPE. Each area has at least one emergency door, known as PPX (personnel protection exit) that is also supervised by the access system. The PPE is equipped with a display panel (at the entry side, screen, and access) that provides the following functions.

i) Exploitation modes console.

ii) Safety veto management.

iii) Chain tests management.

iv) Views to show the status of the area and access and beam conditions, events log, and technical alarms.

The modifications in the EA experimental areas [18], can be summarized as follows:

i) T09 and T10: position of the PPEs changed due to modification of the walls in the T10 and T09 areas.

ii) A new zone, T09-10 will be created consisting of a PPE and a PPX: following the latest RP simulation studies for T09-10, a more restricted configuration of the T09-T10 experimental area PPE will be required. Only authorized persons will be able to change the operation mode (from CLOSED to ACCESS mode) by presenting their badge.

iii) T11: the current PPX will be removed, and a new emergency exit will be installed to allow access the crinoline. The position of the PPE changes also.

A new generation of beam stopper dumps will be installed in new positions. Table 5-7 presents the list of EIS related to the EA experimental areas and Fig. 5-20 presents the future layout.

Table 5-7: EA experimental area EIS.

	T09-10	T09	T10	T11
EIS-Access	PPE T09-10 PPX T09-10	PPE T09	PPE T10	PPE T11 PPX T11
EIS-Machine	T09.TBS017 T10.TBS019	T09.TBS017	T10.TBS019	T11.TBS04

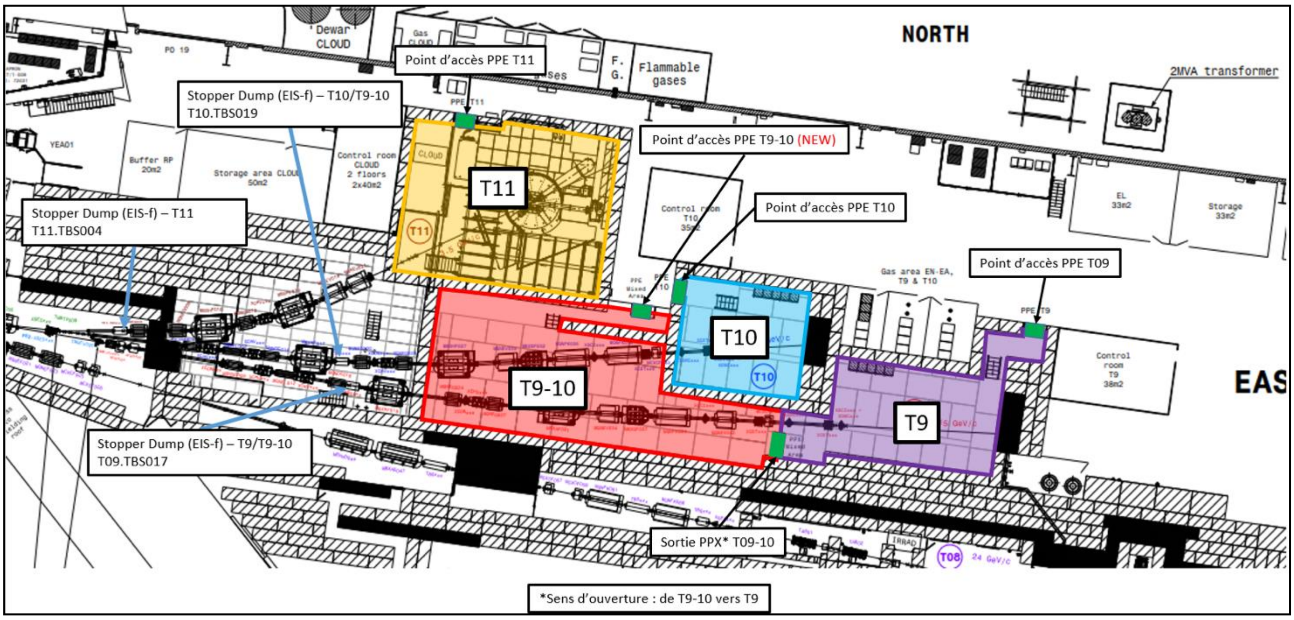

Fig. 5-20: EA experimental areas future layout.

5.8.5.2 PPEs principles

The experimental areas are considered secondary beam zones according to the radiological risk, which is lower than in the primary beam areas. Therefore, only one EIS beam [14] is deemed necessary to interlock the beam. Acceptable EIS can be both physical beam stoppers and interlocks on steering dipole magnet power supplies.

Given the energy of the particles and the low intensity of the beams in the EA experimental areas, beam stoppers are foreseen as EIS, and they must be 'fail-safe', i.e. safe for access when not powered. When a zone has to be accessed, the EIS must be confirmed as being in the 'safe' position. In case of danger detected in the access system, the interlock acts both on the EIS of the area concerned, but also on the upstream interlocked EIS.

The upstream interlock principle also applies. The access safety system will interlock the upstream area in the following situations:

i) Danger for personnel: intrusion in BEAM mode with one EIS-Beam protecting the zone NOT in safe position, loss of safe position of one EIS-Beam of the zone during ACCESS mode.

ii) At least one area in the 'Chain test' mode.

iii) The experimental area operation and access modes are presented in Fig. 5-21.

The current access system is able to manage up to eight areas without major modifications of the central controller in Building 157; it manages the controller of each of the areas according to the defined safety matrix implementing the interlocks.

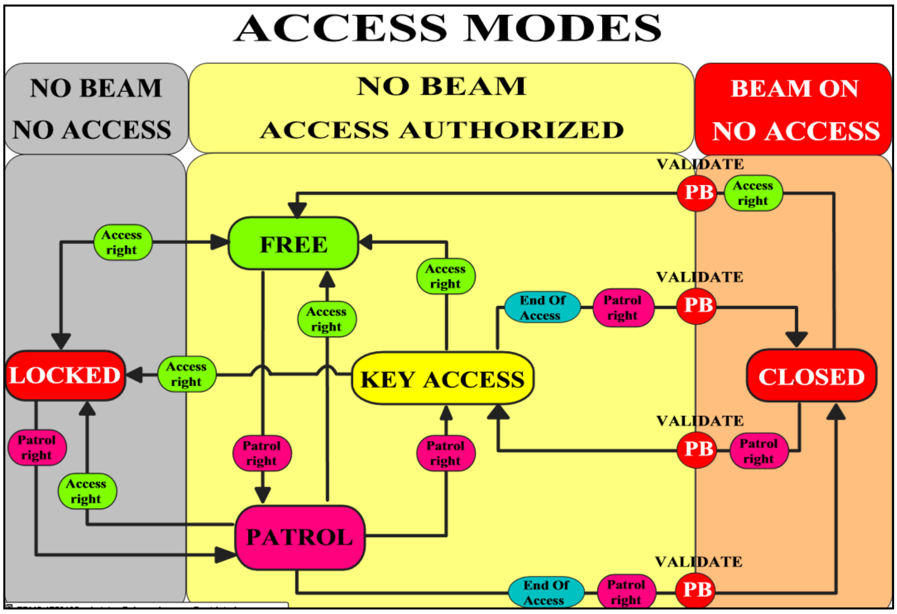

Fig. 5-21: Experimental area access modes – PPE front panel display.

5.9 Alarms

5.9.1 Introduction

In order to reduce the risk of fire and explosion for people, environment, and assets, the following safety system will be implemented in the frame of the renovation.

i) Fire detection.

ii) Gas detection.

iii) Beam imminent warning.

iv) Evacuation plan.

The safety functions of the above systems include early detection, warning occupants and firefighters in case of upset conditions, and automatic protection measures upon detection.

5.9.2 Fire detection

The new fire detection system in the East hall will be an extension of the existing infrastructure, connected to the SFDIN-00324 remote I/O control panel. A new ring connected fire detection loop will be installed as well as its field device and new on-line connected sirens.

Due to the layout of the building and in order to ensure early detection, no smoke detection will be installed under the ceiling but will be installed directly close to the beamlines.

The fire detection system will trigger the following actions:

i) Level 3 alarms to the fire brigade.

ii) Evacuation alarm.

iii) Ventilation stop.

iv) Smoke extraction. A fire risk analysis done in 2017 [19] explains this need.

5.9.3 Gas detection

The new gas detection system in the EA Facility (based on the same standard as in the North Area) will be the state of art SYNTEL distributed control system, which allows the rationalization of the main infrastructure. There will be one SYNTEL common central controller supervising the different experimental installations of the facility and the flammable and toxic gas distribution from the gas barrack to the mixing areas and patch panels. The gas distribution renovation is described in Ref. [20] (see Fig. 5-22).

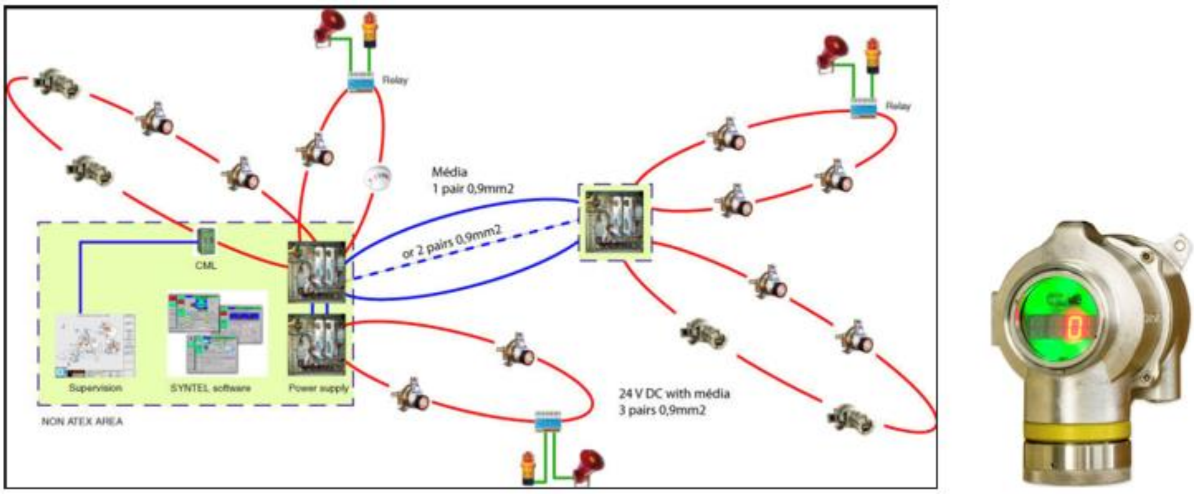

Fig. 5-22: SYNTEL gas detection – flexible technology with addressable devices.

The main infrastructure will consist of the SYNTEL central I/O panel, two racks in this specific configuration installed side by side.

5.9.4 Beam imminent warning (BIW)

The BIW is in use within the radioprotection primary area to warn people before the injection of high-energy particle beams in the machine. In the East Area facility, it triggers the PS access control system.

The new BIW in the East hall will be an extension of the existing infrastructure connected to the SESEV-00224. Fields device such as MACs (manual call point) and sirens will be installed as part of the project scope of work.

5.9.5 Evacuation

There will be an overall evacuation system for the whole East Hall. All the siren sounders will be launched at the same time. They will be connected and triggered by the SFDIN-00324.

A second evacuation system specifically designed for the risks in the primary RP areas of the EA facility will be connected, as presented above, to the SESEV-00224. There will be an interface between the two subsystems.

5.10 Gas systems

5.10.1 Introduction

The EA is supplied by a mixing area and gas piping network coming from a dedicated gases supply building located outside Building 157. This gas supply building is equipped with gas supply panels with connected gas bottles and banks, as shown in Fig. 5-23. It can provide many different types of gases (neutral, flammable) for fixed or temporary experiments in the hall [21][22].

The renovation includes the replacement of the gas supply system and all associated components (pipe and valves) as well as the creation of mixing areas for the premix and adjustment of gas parameters before use by detectors inside the beamlines. The renovation of the gas distribution infrastructure will allow the improvement and standardization of flammable gas safety from the supply building to the final user, in accordance with CERN regulations for safety. The system will follow the ATEX regulations and the global safety will be reinforced by the installation of closed gas racks equipped with ATEX air extraction and gas detection systems that enable the reduction of the ATEX area and restrict accidental leaks to defined volumes.

Another objective of this renovation action is to improve the use of gases between the mixing areas and beamlines (add insulated pipes and components for regulation). This is to in line with requests from many users [23] and also to avoid accumulation of gas equipment not controlled or not correctly assembled. The EA renovation also includes the removal of the gas delivery point to create a dedicated mixing area for the CLOUD experiment.

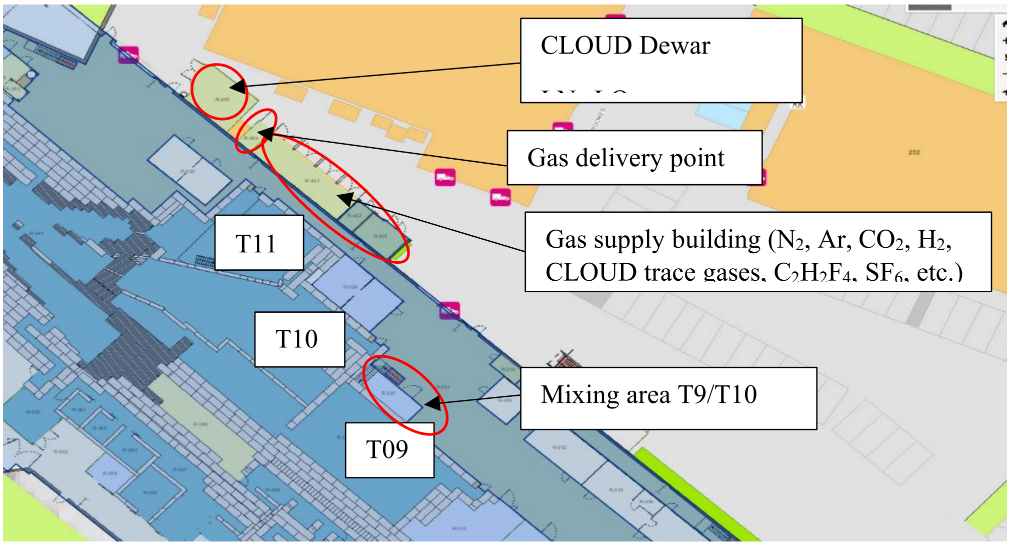

Fig. 5-23: Building 157, current gas distribution infrastructure.

5.10.2 Gas distribution infrastructure for the EA

5.10.2.1 Gas supply building (outdoor)

The content of the gas supply building located outside will be dismantled. The building will be equipped with new gas supply components with remote monitoring as well as a purge system with the possibility of recovering green-house gases (GHG).

The gas supply building will be split into four separate sections (Fig. 5-24):

i) Gas mixing area and Dewar (LN_2, LO_2) for the CLOUD experiment with trace gases (SO_2, DMA, TMB, NAP, TOL):

a. The trace gases will be relocated in a closed safety cabinet with air extraction and N_2 for inertion. The gas supply panels will be replaced by new panels in conformity with safety rules.

ii) Gas supply area for Building 157 (N_2, CO_2, Ar, He):

a. Replacement of old gas supply panels by new switch-over panels located inside closed rack equipped with remote monitoring and exhaust collection.

iii) Gas supply area for flammable or heated gases:

a. Three new closed flammable gas supply racks for T09, T10, and T11. These will be equipped with gas detection, air extraction, remote monitoring, purge collection, N_2 gas line for inertion, and a single gas supply panel (no backup).

iv) Gas supply area H_2 (CLOUD):

a. Change of old gas supply panels by new switch-over panels equipped with remote monitoring, exhaust collection, and N_2 gas line for inertion.

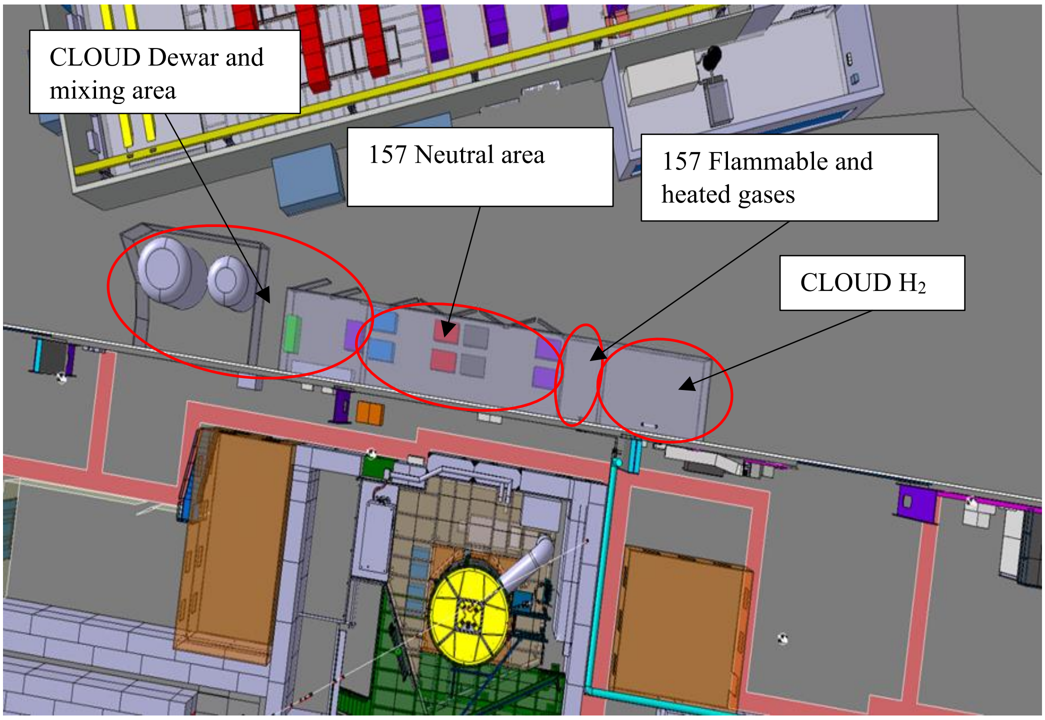

Fig. 5-24: Building 157, new gas distribution infrastructure (outdoor).

5.10.2.2 Gas mixing area T09/T10

The gas mixing area for T09 and T10 will be relocated and split into two dedicated mixing areas per beamline. Each dedicated area supplies the gases inside the beamline via insulated stainless-steel pipes. The closed patch panel for the beamline will be equipped with gas detection, ATEX air extraction, isolating valves, manometers, connectors, safety valves, and two exhaust pipes (flammable and neutral). The connection of the pipes from the patch panel to the experiment will be done via feedthroughs located in the patch panel to restrict a maximum of gas connection to the closed area with air extraction.

The T09/T10 mixing area will be equipped with (see Fig. 5-25):

– Two closed distribution rack for flammable and neutral gases with one linked to the patch panel in T09 and the other with the one in T10.

– Two enclosures (one for each experimental area) for setting up a temporary mixing gas rack (user's equipment).

– Two enclosures (one for each experimental area) for two premixed bottles (neutral gas quality up to 6.0) used for short periods.

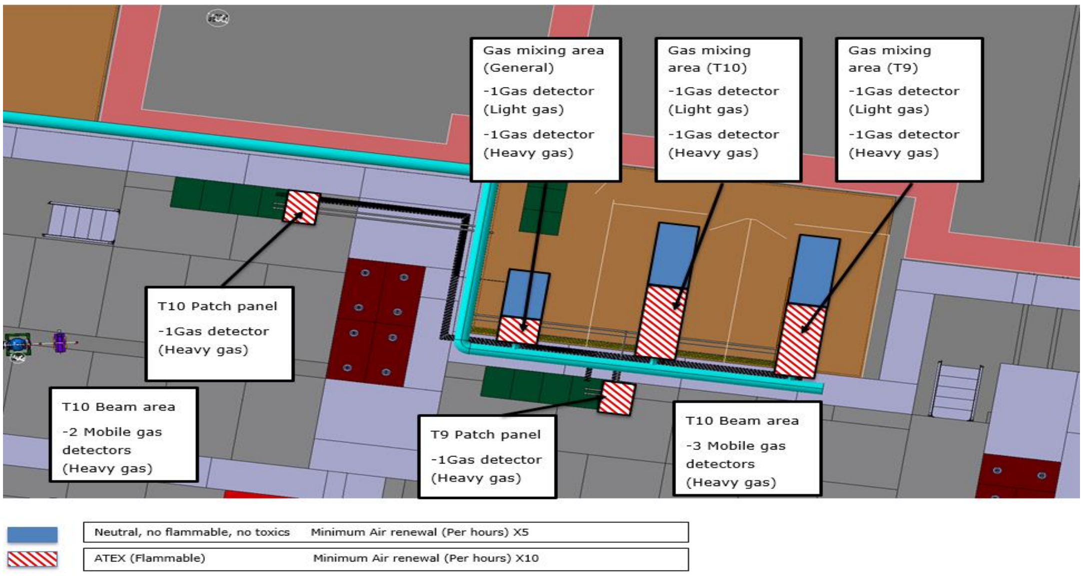

Fig. 5-25: Building 157 mixing area T09/T10.

5.10.2.3 Cherenkov's control rack

The Cherenkov control rack will provide gas (Ar, CO_2, optional refrigerant gases) for the fours Cherenkovs inside the T09 and T10 beamlines. Figure 5-26 shows the gas racks organization.

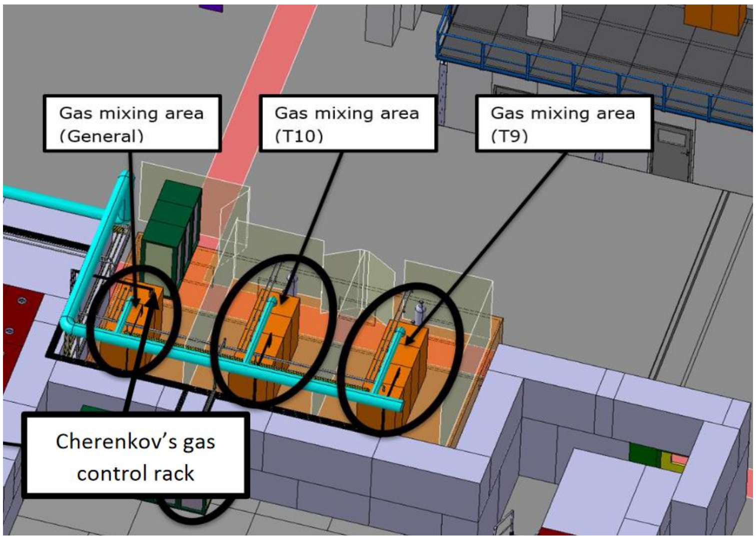

Fig. 5-26: Cherenkovs, gas rack location

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