Resumen

El Cern es el Centro Europeo para la Investigación Nuclear donde se ha llevado a cabo la construcción y puesta en funcionamiento, en Septiembre de 2008, del LHC el mayor acelerador de partículas en el mundo.

El LHC es un acelerador con forma anular de 27 km de perímetro situado a 100 metros bajo tierra en la frontera Franco-Suiza. A lo largo de él se localizan 4 grandes detectores de partículas: ATLAS, CMS, LHC-b y ALICE. Teóricamente se espera que, una vez en pleno funcionamiento, se detecte la partícula conocida como el bosón de Higgs. La observación de esta partícula confirmaría las predicciones del Modelo estándar de la física, pudiéndose explicar cómo adquieren las otras partículas elementales propiedades como su masa.

El LHC es un proyecto de gran envergadura y su funcionamiento depende a su vez del correcto funcionamiento de toda la infraestructura técnica que lo rodea: sistemas eléctricos, informáticos, ventilación y refrigeración, etc.

Todos los sistemas son controlados durante 24 horas al día, los 365 días del año en el Cern Control Center (CCC), situado en Prevessin (Francia). Los operadores del grupo de Infraestructuras Técnicas son los encargados de “vigilar” en todo momento el correcto estado de los diferentes sistemas técnicos.

La activación de una alarma de cualquier tipo y en cualquier localización (electricidad, refrigeración, sistema criogénico, etc.) del LHC es inmediatamente visualizada en las pantallas del CCC por los operadores y son ellos quienes toman las medidas oportunas para minimizar daños. La gran cantidad de alarmas de diferentes sistemas y en diferentes localizaciones que se deben controlar hace que las vistas de las que disponen los operadores en las pantallas del CCC sean de gran importancia para actuar con rapidez y precisión.

Este proyecto ha consistido en el diseño de las vistas utilizadas para el control del sistema de refrigeración del punto 8 del LHC. Se tiene previsto que estas vistas y los prototipos utilizados en ellas sirvan en un futuro para controlar los sistemas de refrigeración en todos los puntos del LHC.

Summary

1. Glossary

Explanation of the terms used in this document:

CERN: European Organization for Nuclear research. It is the world's largest particle physics laboratory.

LCH: Large Hadron Collider, the new particle accelerator at CERN.

ALICE: A Large Ion Collider Experiment.

CMS: the Compact Muon Solenoid.

LHCb: the Large Hadron Collider beauty experiment.

LHCf: the Large Hadron Collider forward experiment.

TOTEM: the TOTal Elastic and diffractive experiment-

AB: Accelerators and Beams Department at CERN.

TI: Technical Infrastructure Section at CERN.

TIM: Technical Infrastructure Monitoring System.

CCC: CERN Control Centre.

TIMRefDB: TIM Reference Data Base.

LASER: LHC Alarm Service.

MoDESTI request: Monitoring Data Entry System for Technical Infrastructure.

EDMS: CERN's Electronic Data Management System

CVS: Concurrent Versions System.

SMILE: Static Monitoring Information Look-up Engine.

2. Introduction

2.1. Motivation of the project

I have been working during the last year as Technical Student in the Technical Infrastructure Section at CERN. In this Section the operators have the mission to monitor and control all CERN's Technical Services, during 24 hours a day the 365 days of the year, ranging from electricity distribution, cooling, ventilation, safety systems and vacuum to control system components cryogenic equipment, lifts and heavy handling equipment. In all there are several thousands of pieces of equipment spread over the various surface and underground sites around CERN.

The motivation of the project arises from the necessity to create clear synoptic views to make the operator's job lighter. With the synoptic reference of the system the operators can localize the alarms quickly, diagnose how important is the problem and repair it remotely, if is possible.

2.2. Aim of the project

The main objective of the project is the design of the synoptic views for the control of Point 8 Cooling Systems in the LHC. At the same time, these interfaces are going to be the standard model for the design of the others Points interfaces in LHC.

The achievement of the objective requires the specification, design and implementation of re-usable symbols to represent valves, tanks, pumps and other equipment where alarms are located.

It has been really important for the successful of the project to be constantly in communication with all the operators of the Section due to they are going to be the final users of the synoptic views and their prototypes.

2.3. Scope of the project

This project is divided in 8 chapters.

The first chapter is a glossary of terms used through the project. Followed by two introductory chapters. One concerning this project itself and the second giving the first introductory vision to what it is CERN, the laboratory where the project has been carried out.

The third chapter explains the Technical Infrastructure group at Cern and TIM, The Technical Infrastructure Monitoring System. The two main applications of TIM, LASER and TIM Viewer, are also explained in this chapter. Although TIM Viewer is explained in detail in the fifth chapter.

Finally, chapter fifth is the one that contains the description of the project for the views design.

Sixth chapter is about Cern and the environment and the seventh is a cost analysis of the project.

In the lasts chapters it will be found the conclusions, the acknowledgements and the references of the project.

3. Introduction to Cern

3.1. Cern

CERN, the European Organization for Nuclear Research, is one of the world's largest and most respected centre for scientific research. Its business is fundamental physics, finding out what the Universe is made of and how it works. At CERN, the world's largest and most complex scientific instruments are used to study the basic constituents of matter.

The instruments used at CERN are particle accelerators and detectors. Accelerators boost beams of particles to high energies before they are made to collide with each other or with stationary targets. Detectors observe and record the results of these collisions.

Founded in 1954, the CERN Laboratory sites astride the Franco–Swiss border near Geneva. It was one of Europe's first joint ventures and actually is composed of 20 member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom *(Figure 3.1)* [1]

Figure 3.1: The 20 members States of Cern

3.2. The Large Hadron Collider (LHC)

3.2.1. How an accelerator works

Accelerators were invented to provide energetic particles to investigate the structure of the atomic nucleus. Since then, they have been used to investigate many aspects of particle physics. Their job is to speed up and increase the energy of a beam of particles by generating electric fields that accelerate the particles, and magnetic fields that steer and focus them.

An accelerator comes either in the form of a ring (circular accelerator), where a beam of particles travels repeatedly round a loop, or in a straight line (linear accelerator), where the beam travels from one end to the other [2]. A number of accelerators may be joined together in sequence to reach successively higher energies, as at the accelerator complex at CERN.

The main components of an accelerator include:

- **Radiofrequency (RF) cavities and electric fields** – these provide acceleration to a beam of particles. RF cavities are located intermittently along the beam pipe. Each time a beam passes the electric field in an RF cavity, some of the energy from the radio wave is transferred to the particles.

- **Vacuum chamber** – this is a metal pipe (also known as the beam pipe) inside which a beam of particles travels. It is kept at an ultrahigh vacuum to minimise the amount of gas present to avoid collisions between gas molecules and the particles in the beam.

- **Magnets** – various types of magnets are used to serve different functions. For example, dipole magnets are usually used to bend the path of a beam of particles that would otherwise travel in a straight line. The more energy a particle has, the greater the magnetic field needed to bend its path. Quadrupole magnets are used to focus a beam, gathering all the particles closer together (similar to the way that lenses are used to focus a beam of light).

Collisions at accelerators can occur either against a fixed target, or between two beams of particles. Particle detectors are placed around the collision point to record and reveal the particles that emerge from the collision.

3.2.2. The Large Hadron Collider (LHC)

The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator and it is also the latest addition to CERN's accelerator complex.

LHC is localized in the border between Switzerland and France about 100 m underground (*Figure 3.2).* It mainly consists of a 27 km ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way.

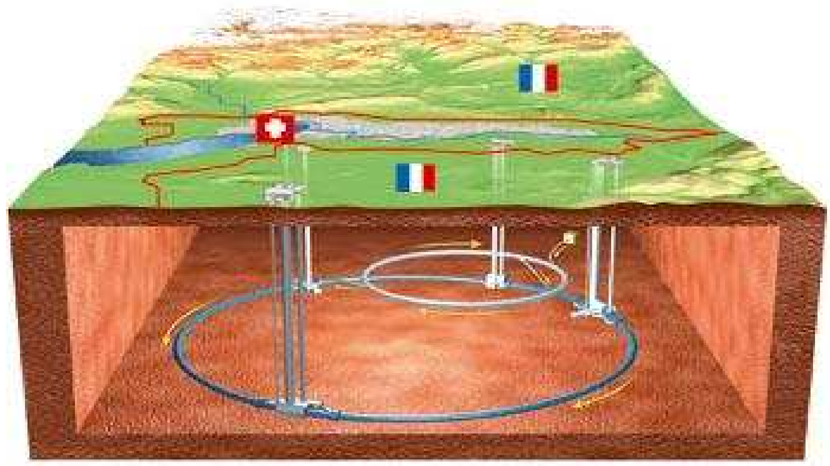

Figure 3.2: LHC's location

The LHC has an eight-fold symmetry with eight arc sections and eight long straight sections *(Figure 3.3)*. Inside the LHC, two beams of particles travel at close to the speed of light with very high energies before colliding with one another. The beams travel in opposite directions in separate beam pipes. They are guided around the accelerator ring by a strong magnetic field, achieved using superconducting electromagnets.

These are built from coils of special electric cable that operates in a superconducting state, efficiently conducting electricity without resistance or loss of energy. This requires chilling the magnets to about -271℃ .For this reason, much of the accelerator is connected to a distribution system of liquid helium, which cools the magnets, as well as to other supply services.

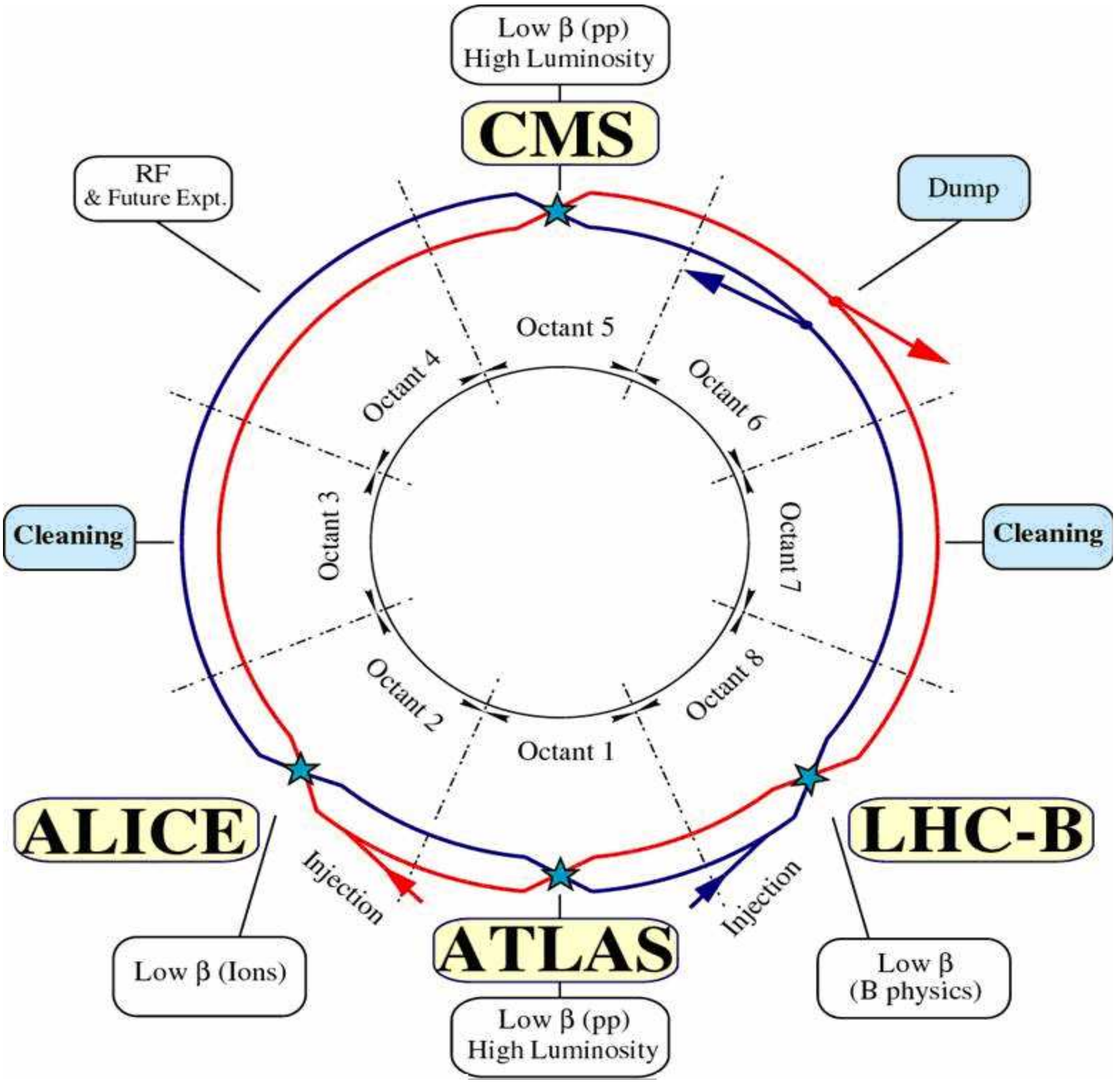

Figure 3.3: LHC Layout

Each arc consists of 23 identical cells, giving the total length of 2465 m. Cells are formed by six 15 m dipole magnets and two quadrupole magnets (these dipoles and quadrupoles are called lattice or main magnets).

Dipole magnets are used to deflect the beam in a circular trajectory whereas quadrupole magnets act as lenses to focus the beam. The lattice quadrupole magnets and the corrector magnets of a particular half-cell form a so called short straight section (SSS) and are housed in a common cold mass and cryostat.

At the beginning and the end of the straight sections a dispersion suppressor cell, consisting of four quadrupole interleaved with four strings of two dipoles each, is in charge of correcting the orbital deviation due to the drift in the energy of the particles.

The four long straight sections where the experiments are located are formed by the dispersion suppressors and the insertion magnets. These insertion magnets guide the separated beams to a common pipe where they are focused by the so called inner triplet magnets in order to get even tighter beams before the collisions take place inside the detectors.

Other insertions are to be used by systems for the machine operation: beam dump, beam cleaning (collimation), RF-cavities (accelerator units) and injection from pre-accelerators.

The injector complex includes many accelerators at CERN: linacs, booster, LEAR as an ion accumulator, PS and the SPS. The beams will be injected into the LHC from the SPS at energy of 450GeV and accelerated to 7TeV in about 30 min. They can be used to collide for many hours.

Thousands of magnets of different varieties and sizes are used to direct the beams around the accelerator. These include the 1232 dipole magnets of 15 m length used to bend the beams, and 392 quadrupole magnets, each 5–7 m long, to focus the beams. Just prior to collision, another type of magnet is used to 'squeeze' the particles closer together to increase the chances of collisions.

3.2.3. The experiments

There are six experiments all around the LHC (*Figure 3.4*). Each experiment is distinct, characterized by its unique particle detector.

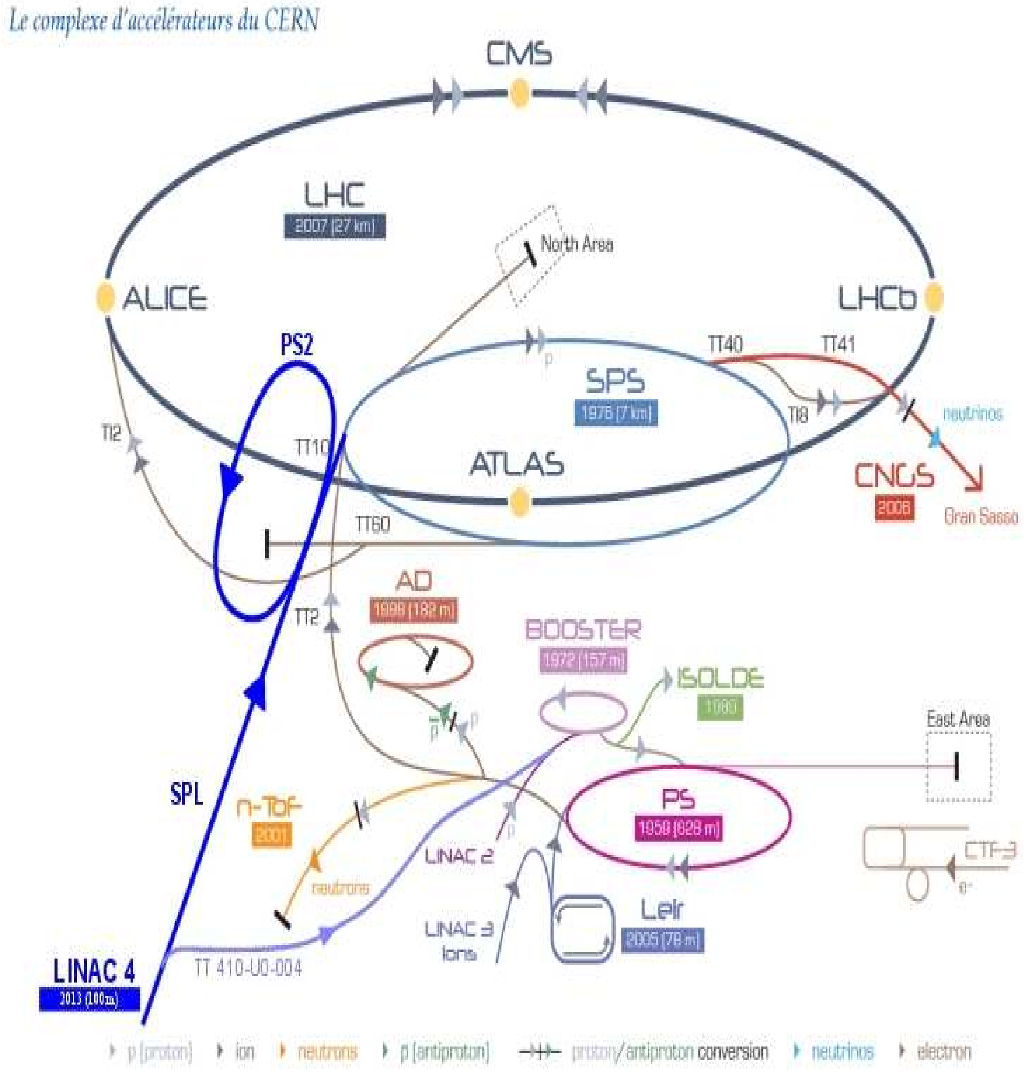

Figure 3.4: CERN's accelerator complex

The two large experiments, **ATLAS** and **CMS** *(Figure 3.5)*, are based on general-purpose detectors to analyze the myriad of particles produced by the collisions in the accelerator. They are designed to investigate the largest range of physics possible. Having two independently designed detectors is vital for cross-confirmation of any new discoveries made.

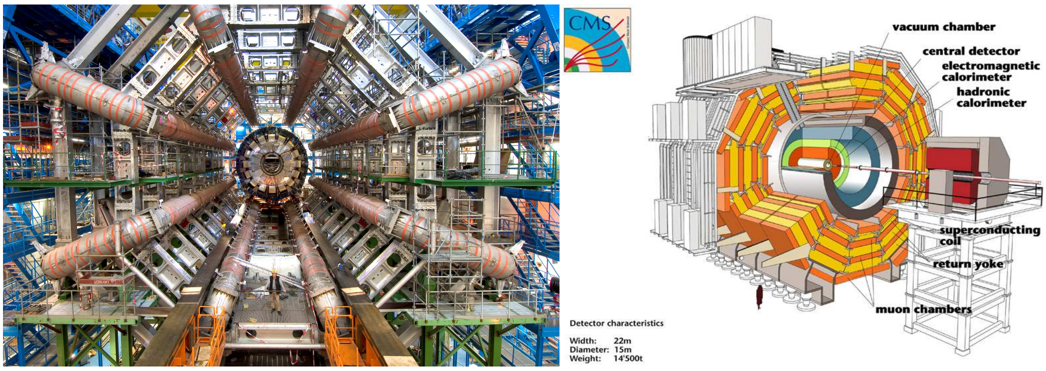

Figure 3.5: ATLAS and CMS

Two medium-size experiments, **ALICE** and **LHCb** *(Figure 3.6)*, have specialized detectors for analyzing the LHC collisions in relation to specific phenomena.

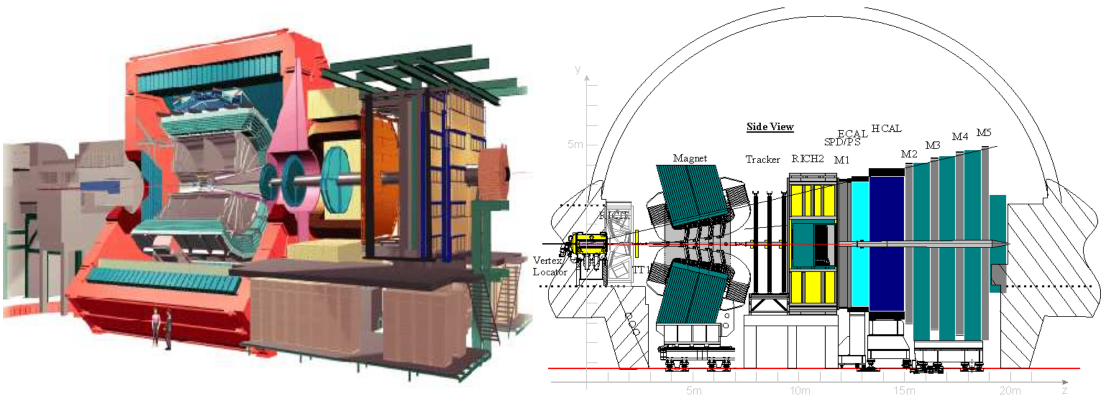

Figure 3.6: ALICE and LHCb

Two experiments, **TOTEM** and **LHCf**, are much smaller in size. They are designed to focus on ‘forward particles’ (protons or heavy ions). These are particles that just brush past each other as the beams collide, rather than meeting head-on.

The ATLAS, CMS, ALICE and LHCb detectors are installed in four huge underground caverns located around the ring of the LHC. The detectors used by the TOTEM experiment are positioned near the CMS detector, whereas those used by LHCf are near the ATLAS detector.

3.2.4. How a detector works

The job of a particle detector is to record and visualise the explosions of particles that result from the collisions at accelerators. The information obtained on a particle's speed, mass, and electric charge help physicists to work out the identity of the particle.

The work particle physicists do to identify a particle that has passed through a detector is similar to the way someone would study the tracks of footprints left by animals in mud or snow. In animal prints, factors such as the size and shape of the marks, length of stride, overall pattern, direction and depth of prints, can reveal the type of animal that came past earlier. Particles leave tell-tale signs in detectors in a similar manner for physicists to decipher.

Modern particle physics apparatus consists of layers of sub-detectors, each specialising in a particular type of particle or property. Depending on the particles or properties that they detect there are 3 main types of sub-detector:

- **Tracking device** – detects and reveals the path of electrically charged particles through the trails they leave behind. There are similar every-day effects: high-flying airplanes seem invisible, but in certain conditions you can see the trails they make. In a similar way, when particles pass through suitable substances the interaction of the passing particle with the atoms of the substance itself can be revealed. Most modern tracking devices do not make the tracks of particles directly visible. Instead, they produce tiny electrical signals that can be recorded as computer data. A computer program then reconstructs the patterns of tracks recorded by the detector, and displays them on a screen.

They can record the curvature of a particle's track (made in the presence of a magnetic field), from which the momentum of a particle may be calculated. This is useful for identifying the particle.

Muon chambers are tracking devices used to detect muons. These particles interact very little with matter and can travel long distances through metres of dense material. Muons can pass through successive layers of a detector. The muon chambers usually make up the outermost layer.

- **Calorimeter** – stops, absorbs and measures the energy of a particle. A calorimeter measures the energy lost by a particle that goes through it. It is usually designed to entirely stop or 'absorb' most of the particles coming from a collision, forcing them to deposit all of their energy within the detector.

  Calorimeters typically consist of layers of 'passive' or 'absorbing' high–density material (lead for instance) interleaved with layers of 'active' medium such as solid lead-glass or liquid argon.

  Electromagnetic calorimeters measure the energy of light particles – electrons and photons – as they interact with the electrically charged particles inside matter.

  Hadronic calorimeters sample the energy of hadrons (particles containing quarks, such as protons and neutrons) as they interact with atomic nuclei.

  Calorimeters can stop most known particles except muons and neutrinos.

  It is usually designed to entirely stop or 'absorb' most of the particles coming from a collision, forcing them to deposit all of their energy within the detector. Calorimeters can stop most known particles except muons and neutrinos.

- **Particle identification detector** – identifies the type of particle using various techniques. Two methods of particle identification work by detecting radiation emitted by charged particles:

  - Cherenkov radiation: this is light emitted when a charged particle travels faster than the speed of light through a given medium. The light is given off at a specific angle according to the velocity of the particle. Combined with a measurement of the momentum of the particle the velocity can be used to determine the mass and hence to identify the particle.

- Transition radiation: this radiation is produced by a fast charged particle as it crosses the boundary between two electrical insulators with different resistances to electric currents. The phenomenon is related to the energy of a particle and distinguishes different particle types.

To help identify the particles produced in the collisions, the detector usually includes a magnetic field. A particle normally travels in a straight line, but in the presence of a magnetic field, its path is bent into a curve. From the curvature of the path, physicists can calculate the momentum of the particle which helps in identifying its type (*Figure 3.7).* Particles with very high momentum travel in almost straight lines, whereas those with low momentum move forward in tight spirals.

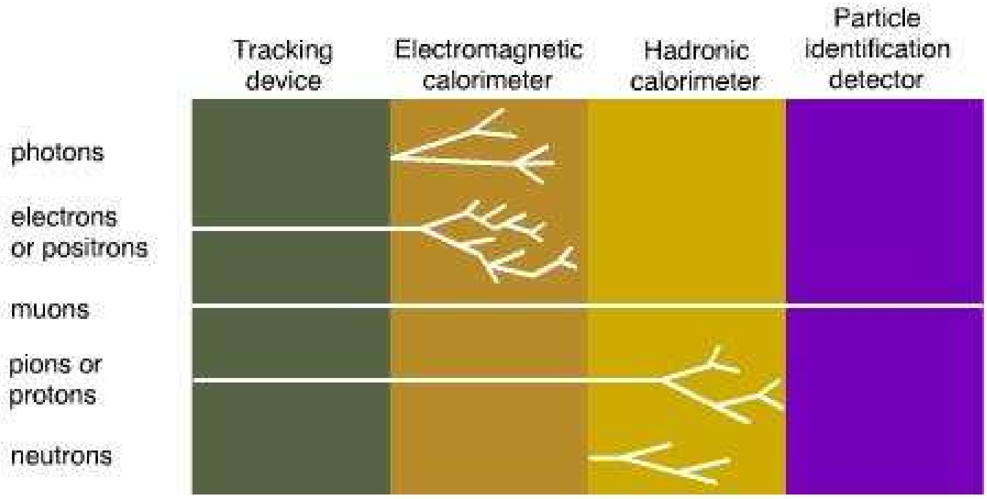

Figure 3.7: Detector and particles detected

3.2.5. Objectives of the Large Hadron Collider

The motivation to construct the Large Hadron Collider (LHC) at the European Center for Particle Physics (CERN) comes from the fundamental questions in Particle Physics.

Our current understanding of the Universe is incomplete. The Standard Model of particles and forces summarizes our present knowledge of particle physics. The Standard Model has been tested by various experiments and it has proven particularly successful in anticipating the existence of previously undiscovered particles. However, it leaves many unsolved questions, which the LHC will help to answer.

- **Higgs boson** – It is observed that some particles are very heavy while others have no mass at all. The photon and the gluons are without mass, while the W± and the Z0 each weighs as much as 80 to 90 proton masses. The most massive fundamental particle found so far is the top quark. It weighs about the same as a nucleus of gold. The electron, on the other hand, is approximately 350,000 times lighter than the top quark, and the mass of the electron-neutrino is < 3 eV. Why is there such a range of masses? The Standard Model explains the origin of mass with the so-called Higgs mechanism which assumes that the whole of space is filled with a 'Higgs field'. Particles acquire their masses by interacting with this field. Particles that interact intensely with the Higgs field are heavy, while those that have feeble interactions are light. The Higgs field has at least one new particle associated with it, the Higgs boson, which has not been observed yet. If such a particle exists, experiments at the LHC will be able to detect it.

- **Supersymmetry** – The Standard Model does not offer a unified description of all the fundamental forces, as it remains difficult to construct a theory of gravity similar to those for the other forces. Supersymmetry is a theory that hypothesizes the existence of more massive partners of the standard particles we know could facilitate the unification of fundamental forces. If supersymmetry is right, then the lightest supersymmetric particles should be found at the LHC. Cosmological and astrophysical observations have shown that all the visible matter accounts for only 4% of the Universe. The search is open for particles or phenomena responsible for dark matter (23 %) and dark energy (73 %). A very popular idea is that dark matter is made of neutral — yet undiscovered — supersymmetric particles.

- **Antimatter** –The LHC will also help us to investigate the mystery of antimatter. Matter and antimatter must have been produced in the same amounts at the time of the Big Bang but from what we have observed so far, our Universe is made only of matter. Why? The LHC could help to provide an answer.

- **Quarks and leptons** – Another question that will be addressed by the LHC is whether quarks and leptons are elementary particles as they seem to be today or if they are made up of sub-constituents. The LHC will also allow precise measurements and tests of the Standard Model (i.e. b and top-quark physics) due to the large available statistics.

- **Quark gluon plasma** – In addition to the studies of proton-proton collisions, heavy-ion collisions at the LHC will provide a window onto the state of matter that would have existed in the early Universe, called quark-gluon plasma. When heavy ions collide at high energies they form for an instant a fireball of hot, dense matter that can be studied by the experiments.

The six experiments will perform the high energy particle physics research in the LHC: ALICE, ATLAS, CMS, LHCb, LHCf and TOTEM.

4. TIM

4.1. Technical Infrastructure Section at Cern

4.1.1. CERN Structure

The organization at CERN is divided in Departments, these departments in Groups and these groups in Sections.

The actual structure at CERN is going to be changed at the beginning of 2009 but during the period where project was developed existed 7 Departments: AB (Accelerators and Beams); AT (Accelerator Technology); FI (Finance); HR (Human Resources); IT (Information Technology); PH (Physics) and TS (Technical Support).

Specifically, this thesis has been framed in AB Department OP Group and TI Section.

4.1.2. Technical Infrastructure Section

Technical Infrastructure is the Section, at AB/OP that looks after CERN's technical infrastructure.

The AB-OP (Operation) group is responsible for the operation of all CERN present and future Accelerators, their associated Experimental Areas and for the monitoring of the overall technical infrastructure at CERN. This responsibility includes: operations staff on shift and their supervision, as well as the supervision and co-ordination of the production and delivery of all particle beams. During periods of operation the group is responsible for the safety and access in the installations. In addition, the groups' responsibility covers the launch, supervision and co-ordination of interventions on the technical infrastructure. Other tasks for the group include participation in machine studies, writing software applications for accelerator control, developing and maintaining some accelerator related hardware, producing and maintaining accelerator operation schedules and providing beam statistics.

Specifically, the members of the TI Section in AB-OP work at CERN Control Centre (CCC). The systems supervised by the Technical Infrastructure operators range from electricity distribution, cooling, ventilation, safety systems and vacuum to control system components cryogenic equipment, lifts and heavy handling equipment. In all there are several thousands of pieces of equipment spread over the various surface and underground sites around CERN. [5]

A failure on a piece of equipment is signaled to the operator either by a user over the phone or by the control system on an alarm screen. It is the job of the operator to analyse the information he receives and to take the appropriate actions.

Their mandate is to minimize the impact of technical breakdowns on accelerators and other important installations at CERN, to manage corrective maintenance activities and to co-ordinate interventions during breakdowns. The operators use TIM to manage their task.

4.1.3. Cern Control Center (CCC)

The Cern Control center is the place where operators of TI Section control all the Technical Infrastructure of Cern. It was built in 2003 with the purpose of replacing four of CERN control rooms: the “Meyrin Control Room” which controlled the PS complex, the “Prevessin Control Room” (PCR) which controlled the SPS and until 2000 LEP, the Technical Control Room (TCR), and the Cryogenics Control Room (QCR). After first contemplating a possible implementation next to the “Globe of Science and Innovation”, it was decided for budgetary reasons to build the new CERN Control Centre (CCC) on the same location as the PCR, in Prevessin.

The CCC layout, seen from the top, resembles the shape of a quadrupolar magnet *(Figure 4.1).* The tables are distributed in four islets of about 5 consoles, respectively dedicated to LHC, SPS, PS Complex and Technical Infrastructure (TI). Cryogenics operations consoles are spread between TI and LHC. In the centre of each islet is a round table hosting 2 computers on the public network, and room for laptops which can connect to the WiFi. A large oval table sits in the centre of the room, providing a social area for discussions between operators. Finally, sixteen 46” screens are mounted on the walls to provide information throughout the control room. Twelve such screens were added after the first year of operation. *(Figure 4.1)*

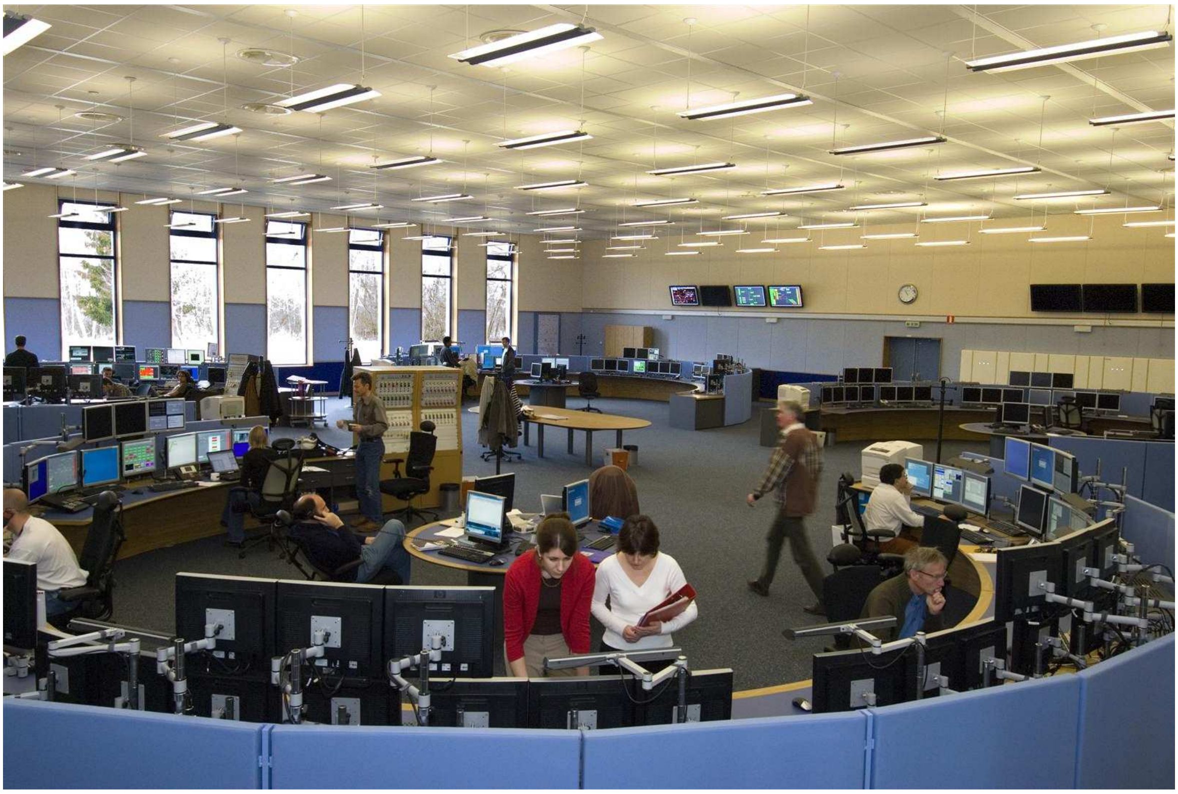

Figure 4.1: Cern Control Center

To understand the importance of the Cern Control Center is necessary to emphasize that the LHC is not an isolated machine: it is fed by a succession of interconnected accelerators. Protons are accelerated and formed in beams in four increasingly large machines before being injected into the LHC. The beams are then accelerated in the ring until their energy is increased by a factor of 15, to 7000 GeV. When that energy is reached, the beamsare going to collide in the centres of the detectors.

The Cern control Center allows controlling all the accelerators from one place. The performance of the LHC depends on the injector chain that feeds it. The cern control centre helps control this extensive process by joining all of the accelerator operators with the engineering and cryogenics departments. By coordinating the process of injection, the CCC guarantees a high-quality beam.

The CCC also manages the beams of CERN’s other facilities. The accelerators of CERN can transport several beams simultaneously and adapt each one to a given facility. It is this ability to deal with several beams at the same time that makes CERN a unique laboratory in its field of research. The 46-year-old Proton Synchrotron (PS), which is the oldest accelerator in service at CERN, prepares beams for the LHC, while feeding the Antiproton Decelerator (AD) and other facilities with various particles.

4.2. The Technical Infrastructure Monitoring System

4.2.1. What is TIM

The Technical Infrastructure Monitoring System (TIM) is the main monitoring tool and alarm gateway for CERN’s technical services and is used to monitor and control CERN's technical services from the CERN Control Centre (CCC). The system's primary function is to provide CCC operators with reliable real-time information about the state of the laboratory's extensive and widely distributed technical infrastructure. TIM is also used to monitor all general services required for the operation of CERN’s accelerator complex and the experiments.

A flexible data acquisition mechanism allows TIM to interface with a wide range of technically diverse installations, using industry standard protocols wherever possible and custom designed solutions where needed . This includes data from the electrical power distribution network, cooling and ventilation systems and other essential services required for the general operation of the CERN sites. Data gathered by the system is presented to operators in the CERN Control Centre (CCC), equipment specialists and maintenance personnel via dedicated graphical applications and alarm consoles.

TIM provides the information to TI operators of CCC with three main computer tools to manage their task:

• A **LASER** alarm screen (or in fact several screens), to get alerted of an event.

• **Synoptic views**, to diagnose a problem and, if possible, to repair remotely.

• A **Computerized Maintenance Management System** (CAMMS) to create and follow-up work orders.

TI operators have access to LASER and Synoptic Views and to all the others tools (smile, help alarm, etc.) trough a website called timweb (*Figure 4.2)* where we can also find all kind of information related with TIM.

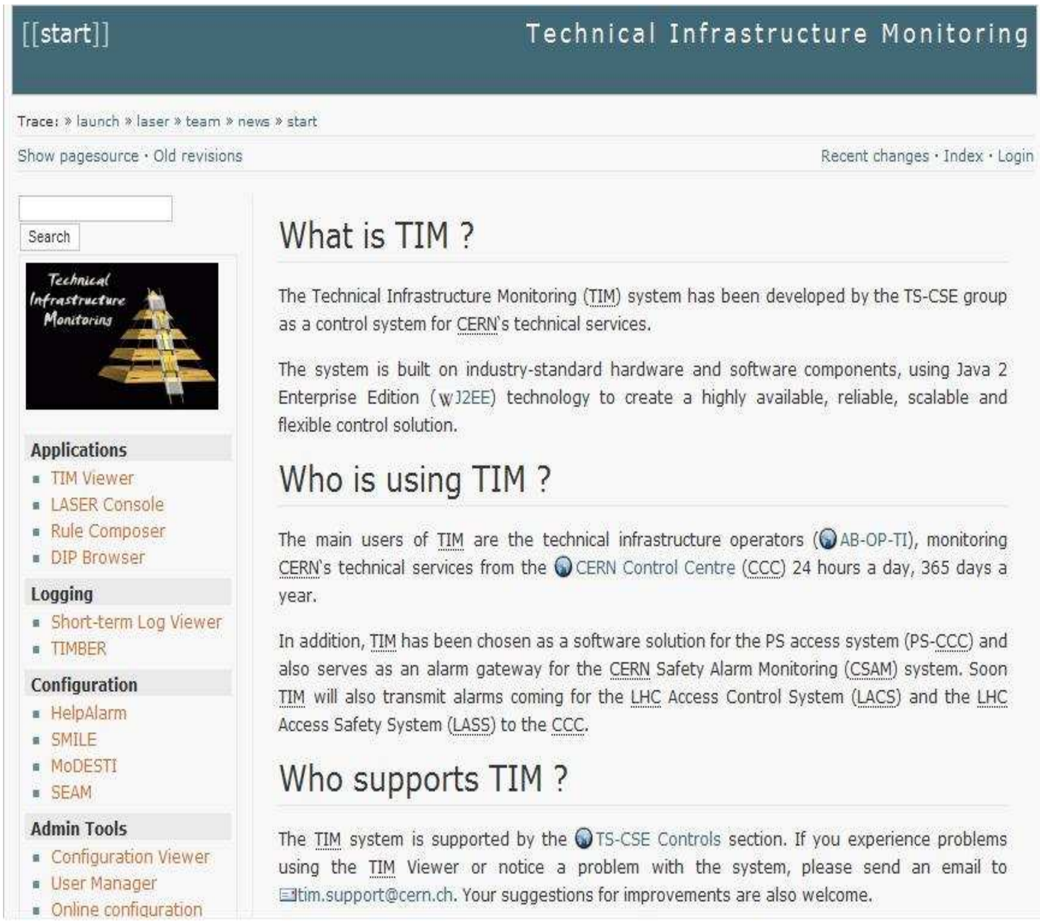

Figure 4.2: website for TIM

The TIM system has to be available 24 hours a day, 365 days a year, in order to ensure round-the-clock operation of the technical services. Reliable technical infrastructure operation is an essential condition for the successful exploitation of the CERN accelerators and experiments.

TIM directly depends on the integrity of the system's configuration data. Erroneous configuration parameters can lead to incorrect monitoring data, false alarms or even partial system failures. Any configuration changes on the operational system are therefore sensitive operations. In order to minimize the risk of applying faulty configurations to the on-line system, all configuration data for TIM is managed in an off-line reference database and only applied to the online system after thorough validation.

4.2.2. TIM's Structure

TIM is a distributed J2EE application deployed in three tiers*:*

- The **data acquisition (DAQ) tier** consists of more than 100 data acquisition modules. These stand-alone Java processes implement the communication interfaces between TIM and the various types of monitored systems and equipment (PLCs, SCADA systems, etc.). DAQ processes collect data from the supervised installations and propagate all significant changes to the business tier. They also take care of command execution and interprocess connection monitoring.

- The **business tier** implements the system's business logic. It processes the data received from the DAQs and distributes it to the clients. Data processing functionality includes data persistence and logging, alarm handling, the computation of composite states as well as system supervision tasks. The business tier also manages user authentication, command execution and access to historical data.

- The **client tier** consists of a suite of graphical tools for visualising the monitoring data acquired by TIM. The main client application is the TIM Viewer, a Java application for displaying animated synoptic diagrams and for performing historical data analysis. Another client application is the LHC Alarm Services (LASER) interfaces used for displaying fault state information on alarms consoles.

In the next page there is a diagram to represent the structure of TIM with the three tiers *(Figure 4.3).*

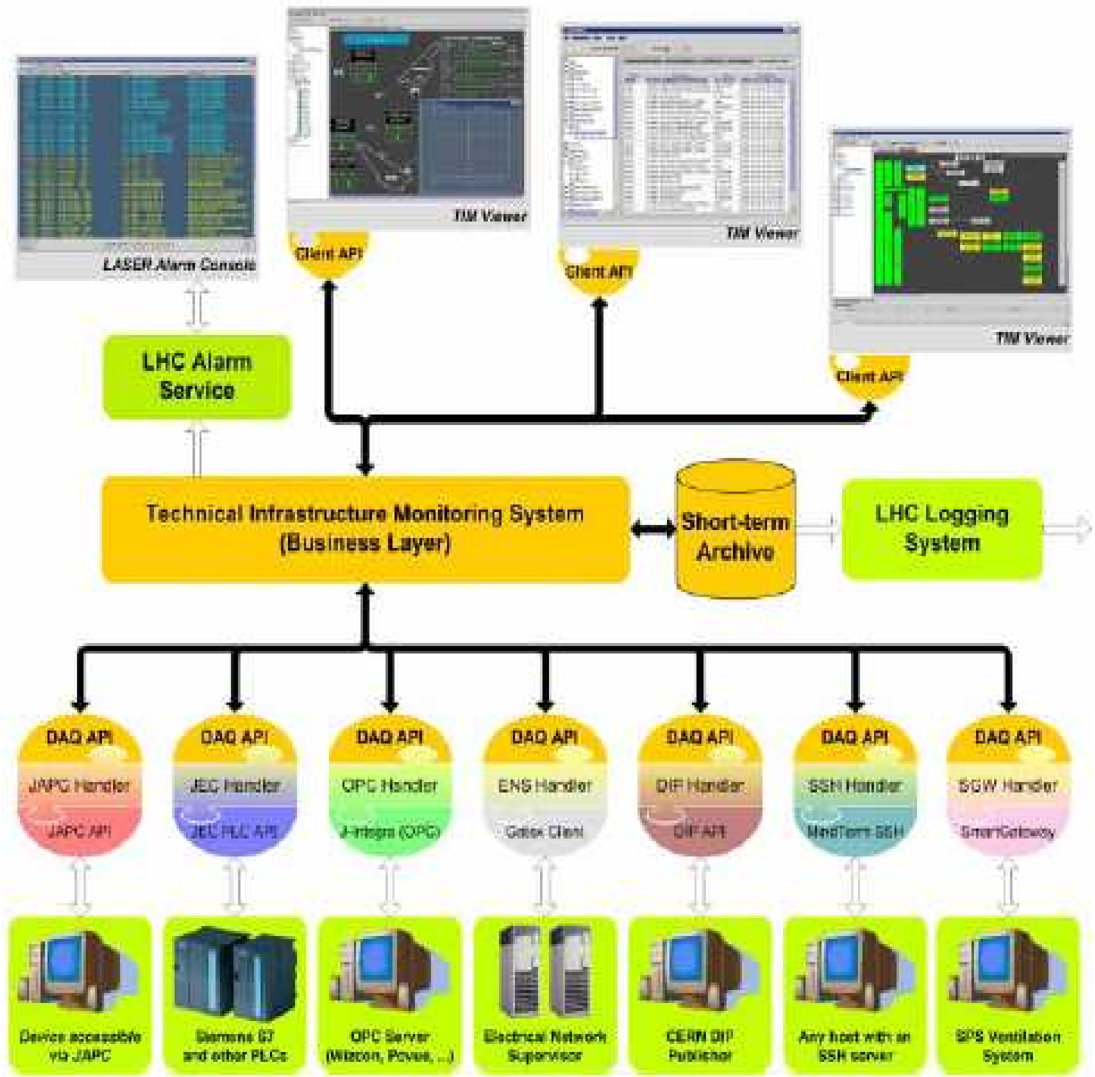

Figure 4.3: Structure of TIM

The tiers are logically and physically separated and communicate with each via a protocol based on a Java Message Service (JMS) middleware. A clean separation of the layers has proven to be very valuable as it limits the dependencies between the different components and facilitates maintenance. [6,7]

4.2.3. Data and Alarm Management in Cern Technical Services

The information processed by TIM is called DataTags and can be classified in alarms and information dates. Alarms are used to get alerted of a possible failure. Information dates are used to get information and usually they are values of Temperature, flows, pressure, etc.

Due to the final objective of TI is taking care of any failure that can appear in the equipment, the great majority of dates are alarms.

LASER application is exclusively for displaying alarms whereas Synoptic Views can display both, alarms and Information Data. In any case the procedure to insert all kind of dates in the database is the same and has several steps defined in next paragraphs.

The Alarm and Data definition process requires several services to work in a specific sequence starting with equipment specialists, involving TI operators and ending with TIM support. Data integration includes cabling to monitoring units, declaration and validation of data in a reference database (TIMRefDB), configuration of the monitoring system, definition of the actions to be taken by the operators (in case of alarms) as well as the testing and acceptance of the dates . To work efficiently and to deal with the growing number of new dates and frequent update requests, this complex process requires coordination.

To manage this process CERN devised the Monitoring Data Entry System for Technical Infrastructure **(MoDESTI).** More information about MoDESTI can be found in *Appendix A*

The MoDESTI procedure is composed of the following components:

- The **standard data entry Excel sheet**.
- The **request creation form:** This is a Web based tool used to create a standard EDMS document describing a request to integrate, modify or remove data on the TIM system. Parameters that will help the follow up of the request are entered with this tool. Only authorised personnel may use this tool, the user's NICE login and password is required to associate the requestor with the request.
- **EDMS**: A dedicated node within the EDMS document hierarchy is dedicated to MoDESTI requests, the list of requests can be filtered using the standard EDMS tools.
- **SMILE (Static Monitoring Information Look-up Engine)**

4.2.4. Description of procedure

The data defining the alarm(s) or the data information is first entered on a standardised **Excel sheet** *(Figure 4.4)* and then submitted to the workflow tool based on CERN's Electronic Data Management System (EDMS). In case of alarm, this tool allows the different people involved in alarm definition to act in the pre-defined order. (More information about how to fill the Excel file can be found in *Appendix B and C*)

The system generates e-mail informing the appropriate specialists about the next steps and actions to be performed or problems to be solved. Moreover, at any moment, the alarm requestor can check the status of his/her request.

GENERAL									LOCATION	
DESCRIPTION	DATA TYPE	EQUIPMENT		SYSTEM	SUB SYSTEM	EQUIPMENT SPECIALIST		ATTRIBUTE	SITE	BUILDING NUMBER
		GMAO CODE	Detail			ID	NAME			
bassin de rejet en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
bassin reservoir en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
tour ETR880 en mode automatique	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
tour ETR881 en mode automatique	Boolean	F$FSEP-02865	ETR881	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
tour ETR882 en mode automatique	Boolean	F$FSEP-02865	ETR882	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
tour ETR883 en mode automatique	Boolean	F$FSEP-02865	ETR883	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
tour ETR884 en mode automatique	Boolean	F$FSEP-02865	ETR884	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
filtre à sable en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
rechauffeur en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
Circuit SH8 en mode automatique	Boolean	F$FSEP-02865	SH8	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
Circuit SU8 en mode automatique	Boolean	F$FSEP-02865	SU8	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
Circuit UW85 en mode automatique	Boolean	F$FSEP-02865	UW85	EAU	Prim	19969	Gros.D	Mode_auto	L08	2865
Arret d'urgence enclenche	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Arret-urgence	L08	2865
Defaut sur onduleur	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Defaut	L08	2865
Onduleur en fonctionnement	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Fonct_onduleur	L08	2865
Presence tension 24V	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension	L08	2865
Presence tension 400V	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension	L08	2865
Presence tension 48V	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension	L08	2865
Presence Air Comprime	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_AC	L08	2865
Presence tension onduleur	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension	L08	2865
Contacteur rechauffeur enclenche	Boolean	F$FSEP-02865	ERA887	EAU	Prim	19969	Gros.D	Contacteur_ON	L08	2865
Disjoncteur ferme	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Disj_Ferme	L08	2865
Disjoncteur ouvert	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Disj_Ouvert	L08	2865
Marche manuel disjoncteur	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Marche_Disj	L08	2865

Figure 4.4: Part of an Excel MoDESTI Sheet

Before the dates are integrated into the system, they are both manually checked by the TI operators and submitted to automatic consistency checks. Only fully verified data is entered into the reference database. Once dates definitions are validated and stored in the reference database, they can be safely configured in the TIM and LASER systems. The configuration of the two systems is synchronised and covers new or deleted dates, as well as changes to data descriptive information.

For testing alarms all new technical infrastructure alarms are initially declared in 'test' mode. These alarms will appear on the LASER alarm screen in a distinctive way so that TI operators do not treat them as real alarms. In case of information data, they are tested in the TimViewer by TI operators too. Once the new dates are tested and conform to the requestor’s needs, they are configured in 'operational' mode.

Once data information or alarms are tested the MoDESTI request *(Figure 4.5)* can be closed.

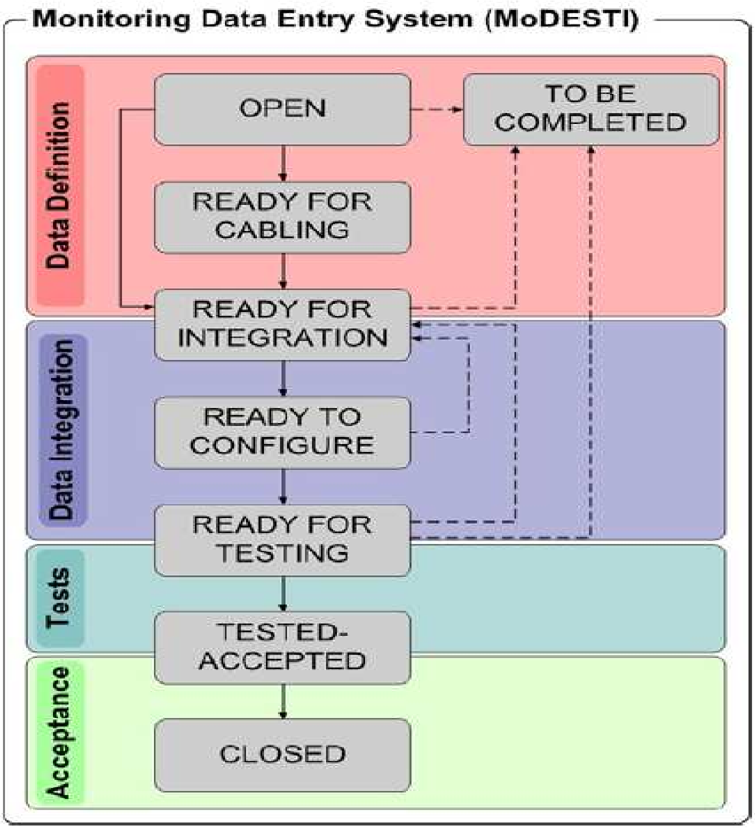

Figure 4.5: Stages of MoDESTI

Once the MoDESTI Request is closed each dataTag (alarm or information data) has a Identification number, usually a six figure number that is unique for each one. This identification number is called DataTag Id and is the information used to design the synoptic Views.

When all the dates are in the Reference DataBase the tool used to get all the information is SMILE (Static Monitoring Information Look-up Engine). SMILE allows users to browse the TIMRefDB and create lists (which can be in Excel format) with all the information about a DataTag or with all the DataTags placed in a building, in a system, etc.

The most used and general option in Smile is the Tag Information-General *(Figure 4.6).*

SMILE

The **S**tatic **M**onitoring **I**nformation **L**ookup **E**ngine is a Web application for browsing configuration data in TIM. Access is restricted to the CERN Intranet.

Reference - Locations	Standard CERN locations on the patrimony database
Reference - Categories	List of valid Alarm Categories
Reference - Systems-Subsystems	The System and Subsystem codes and identifiers used in TIM
Reference - Sites	List of valid Site or Functionality codes
Reference - Attributes	List of currently used attributes
TIM Definitions - Monitoring Equipment	Details on Front End monitoring equipment
Tag information - MoDESTI Request	Tag parameters presented in the MoDESTI input format
Tag information - General	Essential TIM tag parameters
Tag information - Source	Monitoring source address parameters for TIM tags
Tag information - Alarms	Detailed TIM Alarm information
Tag information - Alarm reduction	Alarms masked by another alarm (e.g. Maintenance Mode)
Tag information - Tag states	TIM tags state values
Tag information - Analog points	Details of analogue points handled by TIM
Tag information - Command points	Details of command points handled by TIM
Tag information - Tags published to DIP	Details of TIM tags available to external clients through DIP
Tag information - Rules	Definition of TIM rule tags
Tag information - CSAM	Monitoring tag details for safety systems handled by CSAM
Tag information - CSAM SNAPSHOT	Safety tags - VALID TILL LAST NIGHT ONLY!

Figure 4.6: Smile

In the General option of Smile it's only necessary to fill one of the fields that is known and all the information that is wanted to know about.

In the example of the next figure *(Figure 4.7)* is possible to see all the options or information than smile can offer. In this example is used a DataTag Number (122166) to obtain the System Name, the Building Number, the Alarm Id, the Tim Tag Name, the subsystem Name and the Point Description of this DataTag.

On the left hand corner is possible to choose the format to receive the information. The most common format is Excel.

A selection criterion is mandatory otherwise the selection will not be executed, this is because the database contains around 24,000 records and such a list is of no practical purpose.

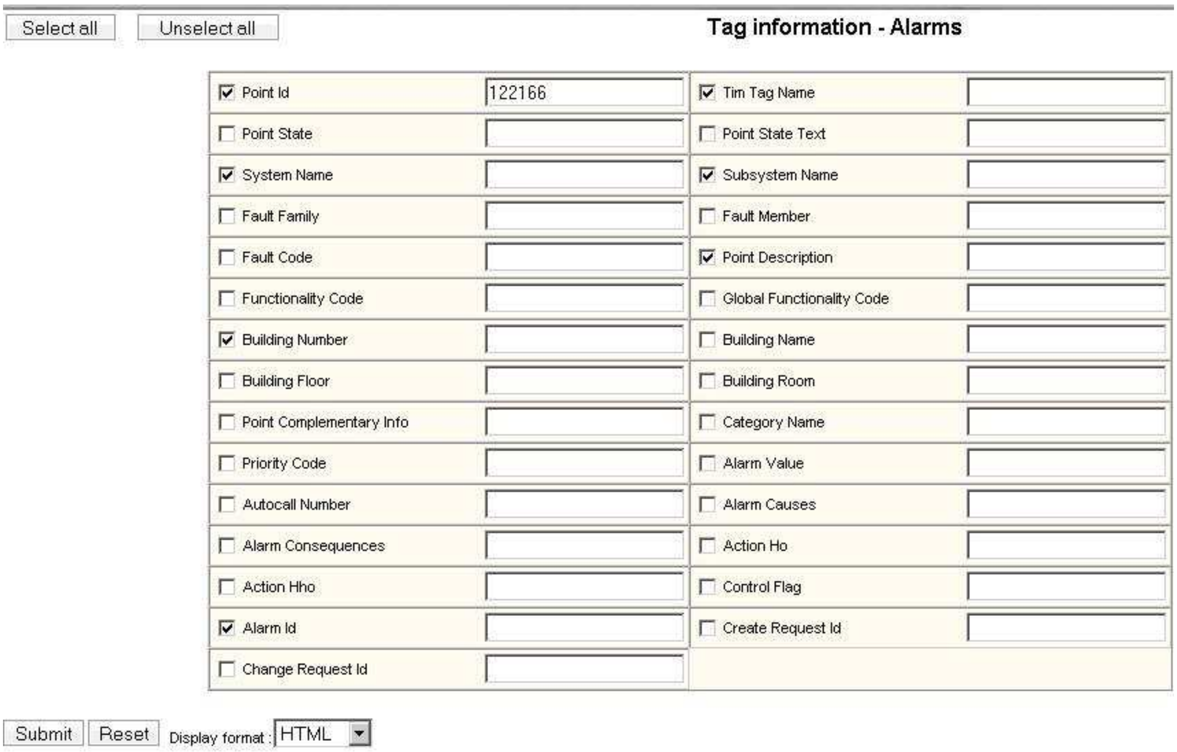

Figure 4.7: Options in Smile

4.2.5. TIM in numbers

The TIM system currently handles more than 25,000 input signals, comprising 22,800 equipment states and 2,200 digitised analogue measurements. These signals are acquired from a variety of SCADA systems, PLCs and custom-built software systems via more than 100 DAQ processes. In addition, TIM handles 900 digital and analogue commands.

There are ~19,000 equipment state alarms defined in the system database for reporting abnormal situations and problems with the technical infrastructure to the LHC Alarm Service. The values of 700 analogue measurements are regularly transmitted to the LHC Logging System for long-term storage.

In a normal production state, TIM processes on average 1.3 million value changes per 24-hour period.

TIM regularly has ~100 users connected to the system at any given instant using the TIM Viewer but this number is expected to rise considerable next years. Also the number of DAQ processes is expected to rise by 50%. The scalable design of the TIM system will allow us to increase the data processing capacity of TIM beyond these limits if necessary.

4.3. LASER

4.3.1. Definition of an alarm

Alarm management in the heterogeneous environment of the CERN technical services is a complex and sensitive domain. Not only do the technical components such as data collection, transmission and display have to be robust and sophisticated, catering for a wide variety of situations and functions, but the definition and maintenance of the alarms has to be rigorously applied. The alarm service for LHC (**LASER**) is the system that takes charge of the matter.

The notion of alarm differs in different organizations and in different tools and applications. At CERN and in the context of control room monitoring, an alarm is defined as an event that needs operator attention and action. An alarm is directed towards an operator who must have a fundamental understanding of layout, processes and systems. An alarm cannot carry all information necessary for the appropriate response. If an event does not need operator attention, it should not be displayed on the alarm list but rather stored where it can be found on request, for example on a separate event list.[8]

An alarm is displayed as a single line on an alarm list and carries basic information. (*Figure 4.8)*

Figure 4.8: LASER Console

- Information directly visible on the alarm list:
    - Date and time of the event.
    - System/subsystem/functionality; a short text describing what system is concerned.

- o Detailed location information; building, floor, room.
- o - Equipment name/code; a name used by the equipment owner and if possible by the maintenance management system that uniquely identifies a piece of equipment.
- o Problem description; a text describing the event
- o Priority; displayed by text colour from the highest priority, 3 in red, through level 2 in yellow and level 1 in blue down to the lowest priority, 0 in white o State; an active alarm is displayed in a colour corresponding to its priority level (3 red, 2 yellow, 1 blue and 0 white) and is displayed in green when terminated.(Table 4.1)

Alarm level	Meaning	Action to be taken	Display colour
Level 3	Presence of a potential danger to human life, property or the environment	Immediate intervention by the Fire and Rescue Service (SCR)	Red
Level 2	Malfunction of an item of equipment or an abnormality equipment or an abnormality which could result in a level-3 alarm	Immediate intervention equipment or an abnormality (TCR or by the competent technical service group technically in charge)	Yellow
Level 1	Fault in a piece of equipment or an installation which cannot immediately result in a level-3 alarm	Intervention by the competent technical service (TCR or group technically in charge)	Blue
Level 0	Normal State	No action to be taken	White

Table 4.1: Alarm meaning

- Configuration information (Data source, address, responsible, etc.)
- Additional operator help information (Cause, action, maintenance management codes, alarm instructions).

4.3.2. LASER's Architecture

The alarm system known as LASER is made from 5 main components on 3 tiers (*Figure 4.9*).These being: sources, the middle tier services, the database, message orients middleware (MOM) brokers and operator consoles.

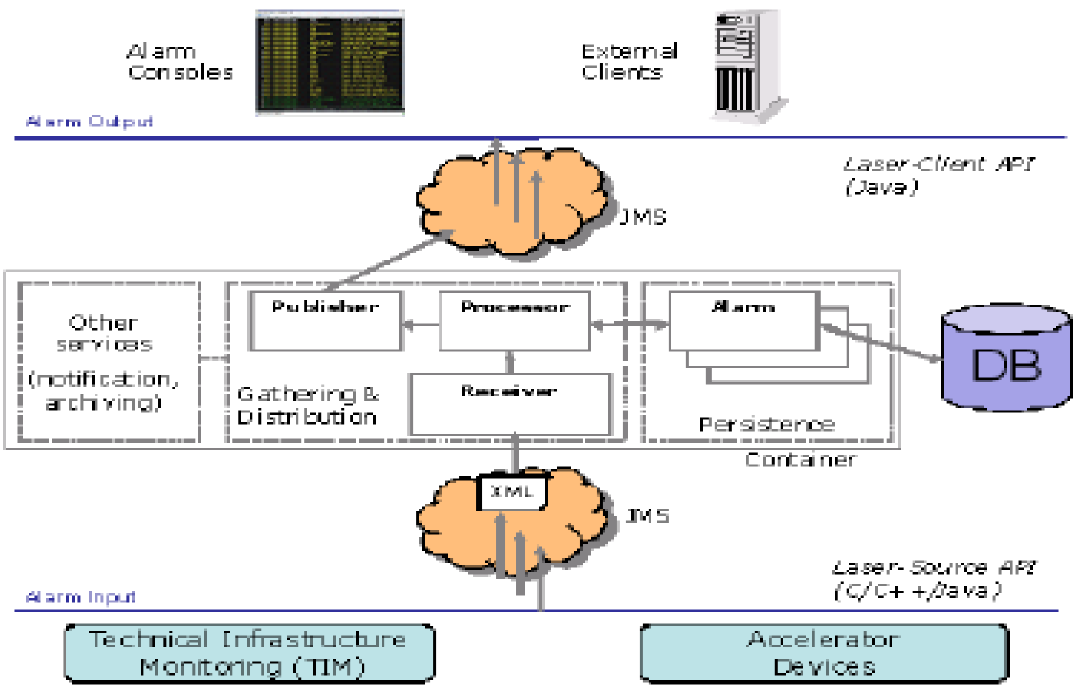

Figure 4.9: Laser components

The **MOM brokers**, running as a highly available cluster, provide a communication service between all the tiers. The database also has redundant instances for storing alarm definition data as explained above.

Sources send alarm events to the middle tier and these contain an alarm identity, timestamp and state (active or terminate). Sources are software processes, created and maintained by alarm providing clients, which monitor their infrastructure or accelerator subsystems. Each one is monitored by LASER, and if any fail, then an internal alarm is raised to notify operations of this problem.

The **middle tier processes** incoming alarm events, does some verification such as checking that the identities are valid, then stores the event, and delivers any necessary alarm change to the consoles along with its corresponding definition.

Finally, **consoles** subscribe to categories of alarms, which are descriptive subsets of the total set focused on users. Consoles show alarms as they occur, and also provide access to the archive, and other alarm information. Other external software clients can also subscribe to alarm output.

LASER handles the alarm tools and event delivery, however, the quality of alarm data depends primarily on the definition process.

4.3.3. Alarm System Availability

Alarm systems in general, and LASER specifically, should work “correctly” and always be “available”.

In terms of “continuous availability”, LASER relies on a set of other physical services such as its server machines, as well as a set of infrastructure services such as networks, and databases. It also itself is composed of components, such as the MOM brokers and sources. It is virtually impossible to guarantee that all of these can provide a continuous service under all circumstances.

Having acknowledged that some of this can fail it is important to make the failure and the consequences obvious so it can not only be fixed, but also so it can be understood that unaffected parts of the system can still be used and will behave correctly. For example, it is possible that the archiving in LASER can fail (perhaps due to a database problem), but alarm event delivery from sources to consoles will continue unaffected. LASER was designed to be failsafe such that alarms are generated and displayed if there is any doubt. If at any time a failure could cause misunderstood behaviour, it is better for the system not to be available. It is important that operators, providers, and developers, all have a correct mental model of how the alarm system functions, in terms of expectations and behaviour, or the system cannot be exploited to its full value.

The alarm consoles provide supervision of the LASER system itself, for example by showing different icons according to the availability of the alarm server.

Another aspect of correctness is that of the alarms themselves. The alarm is only as true as its input, for example, a sensor. A common problem is alarms coming from hardware with analogue input converted to binary decisions. Without proper tuning, it can sometimes be unclear to the surveillance system whether the alarm should be active. As such alarm "truth" is approximate and at finer granularity, indeterminate. Time is another aspect of this problem. Adding a timestamp to an alarm event requires an understanding of the accuracy and precision of the time source.

At some point in the life of an alarm system, a serious situation *will* occur. It is very important to focus on learning from the outcome to improve the system to reduce a reoccurrence. It would be unfortunate that only when a serious or costly failure (sometimes involving insurance, safety, or legal issues) occurs, is any lack of resources closely examined. [9]

4.3.4. Other LASER Services

LASER also provides some additional services available in the console.

- **History** – Any alarm may have a history of events associated with it, the console can request and show the previous times the alarm was activated or terminated, up to the last 6 months. It is useful for operators to know if that alarm had occurred before, when and how often.
- **On-screen search** – For when there are many alarms, a quick search facility highlights alarms on the console with the requested text.
- **Archive –** the alarm system stores all events for 2 years. This archive can be searched for sets of alarm events. This is for discovering patterns of problems, investigations and auditing. For example some computer equipment had been stolen a few months

previously, and it was possible to discover exactly when from the alarm archive, by examining the network alarm events around the time. General statistics are gathered for reports as well.

- **Alarm definition information –** The global known set of definitions is available for consultation.
- **Diagnostics –** The console can embed components that can request further information and display it directly from a subsystem.
- **Alarm list export –** The alarm system allows exporting all lists (active, history and search lists), not only to a printer, but also as a comma separated values (CSV) file attached to an email.
- **Alarm Help –** Although most alarm information is held within the alarms configuration database, there is a need to be able to link an alarm to additional information. This link enables LASER to show this additional information in a web browser. Technical infrastructure operation uses this link to what is known as the *Help Alarm* application.

Furthermore, other visual components can be used, for example, one component for accelerator operators shows detailed equipment status with appropriate basic commands such as reset.

4.3.5. Help Alarm

Help Alarm (HA) is a web based GUI *(Figure 4.10)* to display additional information about an alarm.

It allows knowing information about the location, the equipment, etc. where the alarm is placed. The type of information that help alarm can display is described in points just after the figure.

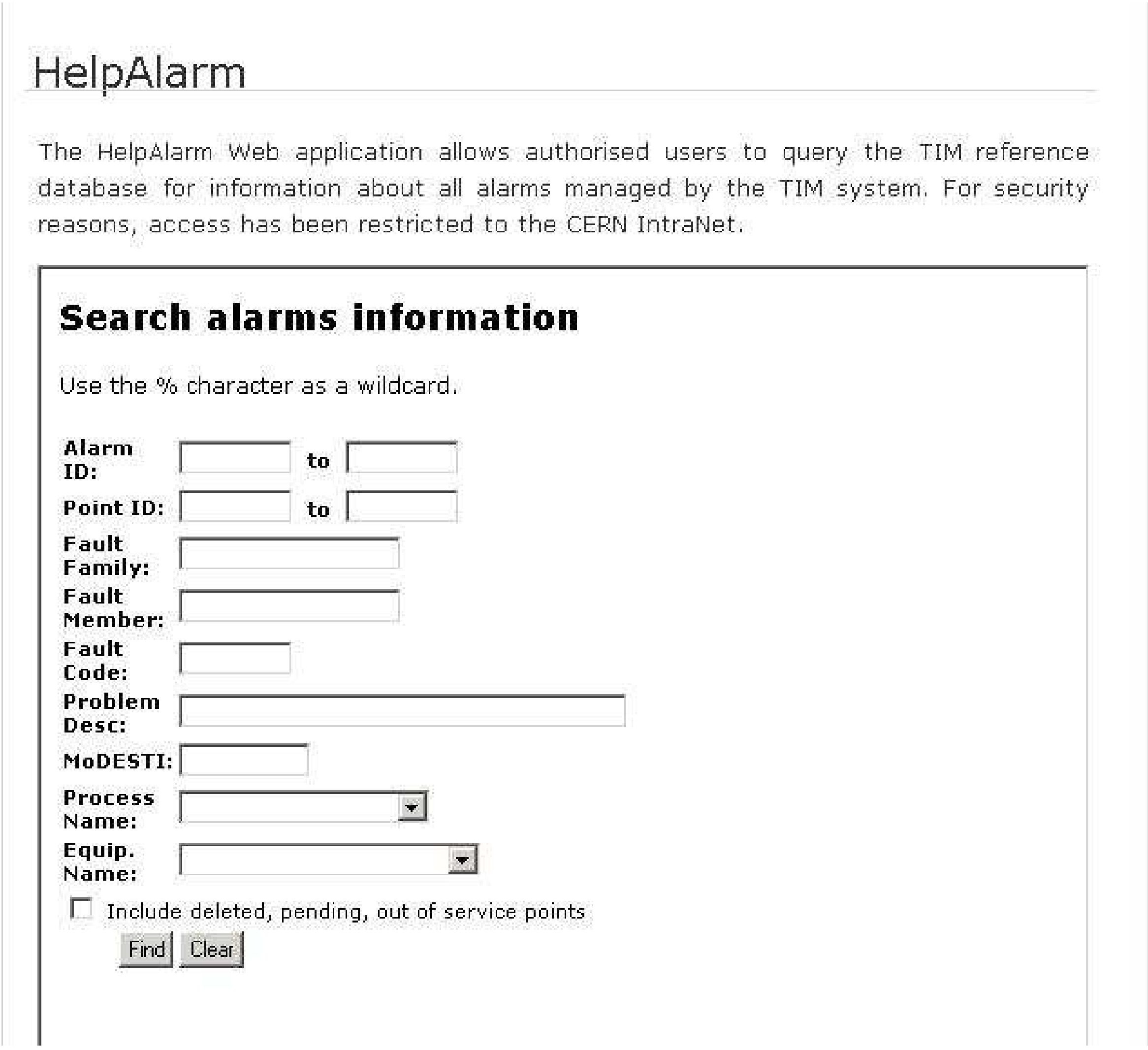

Figure 4.10: Help Alarm

• **Cause, consequence and actions for the alarm –** defined in collaboration with the alarm owner, and changeable directly on the HA interface, should it need to be.

• **Alarm instructions –** information from the equipment owner or intervening personnel concerning the alarm.

For instance, that the alarm should be inhibited for a few days while a spare part is being ordered. A history of all instructions ever issued for a particular alarm is available as a link,

• **Past maintenance orders –** a list of the 4 last maintenance orders issued for the equipment at fault. The list shows dates and states of the maintenance orders and gives links to more detailed information directly from the maintenance management system.

All work orders issued for the same alarm are easily accessible along with the comments about the work done. This is valuable information for quick interventions in case of repeated problems.

• **Contact information for the equipment responsible –** Name, telephone and email address.

• **Alarm configuration information –** such as monitoring equipment details, references to any existing MoDESTI requests. This section also contains a direct link to the TIM alarm information to allow visualisation of the alarm concerned, which is often used for trouble shooting.

Help Alarm currently only exists for technical infrastructure alarms from the TIM system, but it has shown to be so useful that it should be extended to other systems. By giving the possibility for *on-line* data modifications, Help Alarm aids in keeping the alarm information up to date; an operator can easily initiate a modification directly from the GUI.

Another service connected with alarms is the *Alarm Notification System* (ANS); equipment groups can define *call-out lists* which are lists of telephone numbers to be called on the arrival of an alarm. It is possible to configure the LASER alarm system with an ANS identifier so that, when an alarm is activated, the corresponding identifier is sent to the ANS. In this case, the console alarm will be prefixed with an [A] to let control room operators know that an automatic notification has been issued. The notification can take the form of a telephone call, an SMS, an email message or any combination of these. An acknowledgement of the reception of the automatic call is sent to the control room operator by email.

4.4. TIM Viewer

The TIM Viewer is the main user interface to the TIM system. It main purpose is to visualise monitoring information acquired and processed by TIM in synoptic diagrams and trends. It is the main tool used by TI operators, as well as LASER, to supervise all the technical systems.

TIM Viewer allows displaying all kind of DataTags, alarms or information Dates. Moreover, it allows making views that represent the real aspect of the equipments and where they are placed. It makes easier the job of operators.

All TIM Views are managed using CVS and then automatically deployed to the operational platform. CVS is used to test new views, to put them in operation, to release new version, and to eventually take them out of operation.

4.4.1. JViews Composer

JViews Composer is the graphic editor that TIM uses to develop the prototypes and synoptic views. This application combines a fast application development tool for quickly configuring a diagram display, with a comprehensive Software Development Kit (SDK) for providing specialized functionality to the prototypes. It allows the design and making the Java code from the same place.

Into the JViews Composer the prototypes are distributed in libraries depending of they are used for: lib_elec, lib_cooling, etc. In the case of this project all the protototypes created are located in lib_cooling.

JViews Composer allows to manage views with a good graphical quality and, at the same time, allows us to develop a Java code to decide how our prototypes are going to display the information in the TIM Viewer.

The procedure to design a prototype and to design a view is described in detail in the next chapter.

4.4.2. Organization of the Views

The Views in the TIM Viewer are organized hierarchically, as a tree, in three main categories:

- **Production**: The Production folder contains all views that are considered operational**.** A view is considered operational when it is tagged PRO in CVS.
- **Next**: The Next folder contains the latest version of all views in CVS if the latest version is different from the production version or if no production version is available (yet). As such, the Next folder can be used for testing new (versions of) views before putting them in production or for temporary views that need not be accessible in the production environment.
- **Previous**: Whenever the production version of a view changes, a backup copy is kept in the previous folder. Also when a view is removed from the repository a copy will be kept in Previous.

Underneath these high-level categories, the views are organized in simple folders, as decided by the view developers.

Firstly all the views created are stored in Next folder. If the view is commited then all the users can see the view, on the contrary, if the view is not commited the view can only be opened from the local folder of the designer.

4.4.3. TIM View Management in CVS

CVS, Concurrent Version System, is the software revision control system used at Cern to organize all the Views in TIM Viewer. Basically, version control system software keeps track of all work and all changes in a set of files, and allows several developers (potentially widely separated in space and/or time) to collaborate. Moreover it allows working locally with views and sharing these views when the designer consider suitable.

The system works in the way that the user has a local home directory, this directory can be found in C:\Documents and Settings\nice_login**.** In this directory, there is a subdirectory called tim-views containing all TIM views currently managed in CVS. These TIM Views are usually distributed in folders.

To create a new view is necessary to follow several steps that has been tried to be explained in the next figures and points:

- Save the new view file to a subdirectory in C:\DocumentsSettings\nice_login\tim-views. Open the directory in a Windows explorer window, right-click on the file to be added and choose "CVS Add...**".** Files that have not yet been added to CVS can be easily recognized by their question mark icon. *(Figure 4.11)*

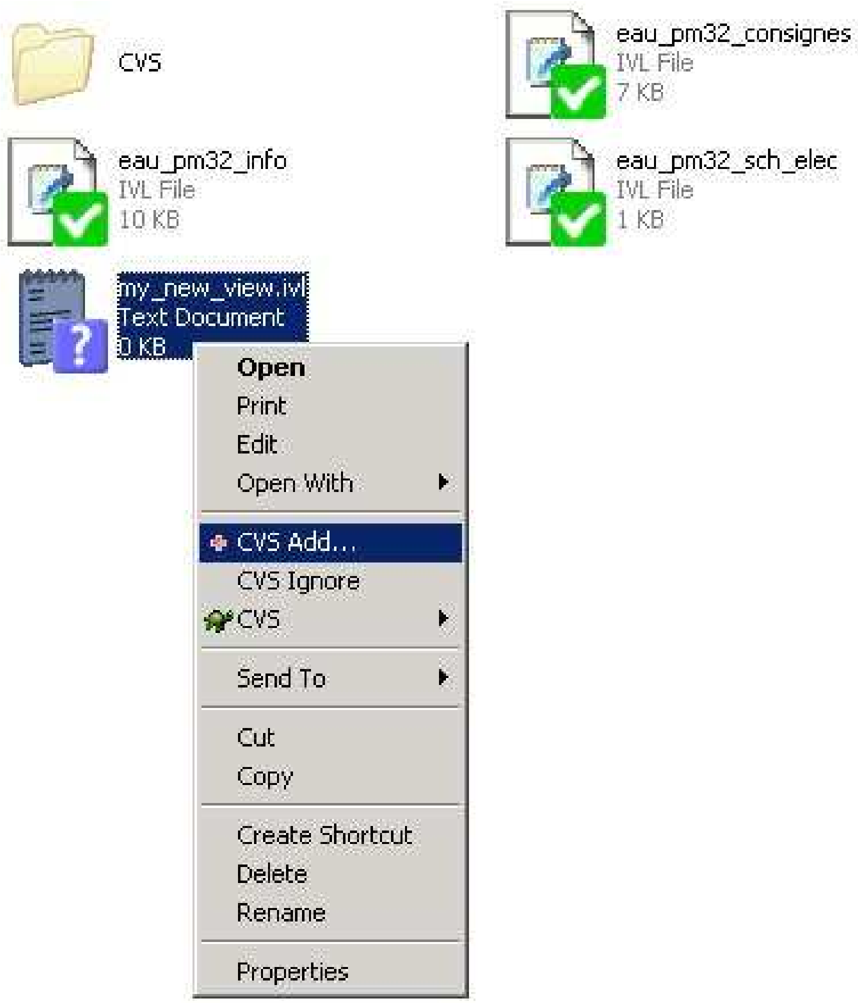

Figure 4.11: Adding a new view with CVS

- Once the file has been added to the CVS repository, is necessary to commit a first version by, again, right-clicking on the newly added file and choosing "CVS Commit...**".**Then it appears a screen for a comment and confirmation *(Figure 4.12).* After committing, the icon of the file should change to a green check mark.

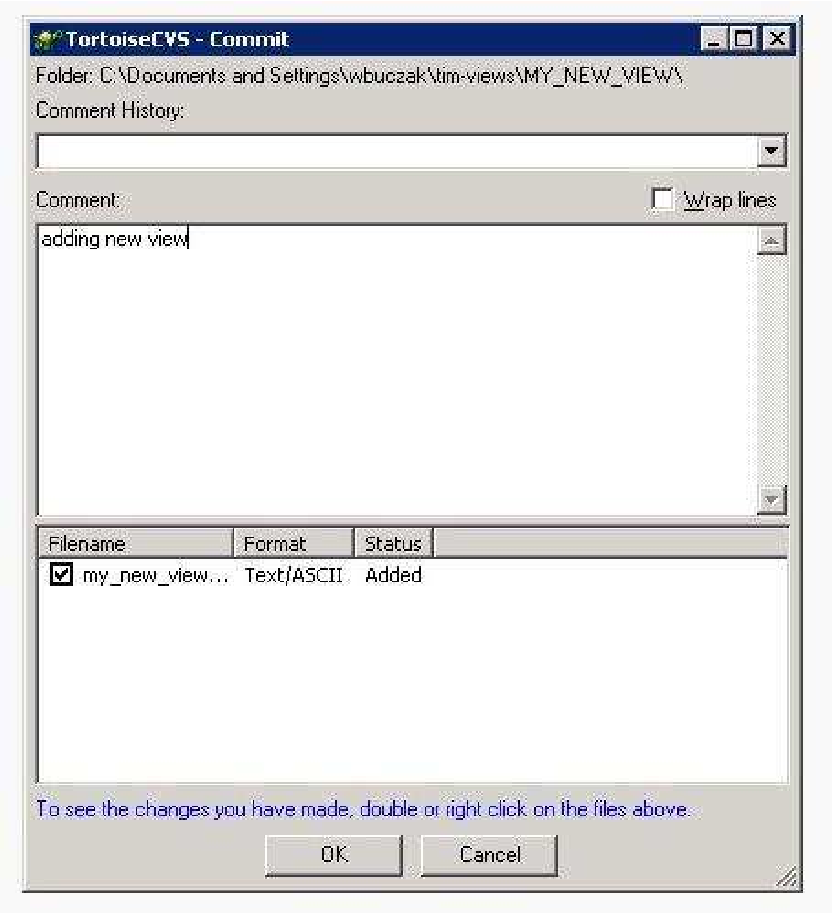

Figure 4.12: Comments after commiting

To tag a view is necessary a right-click on the file and choose CVS⇒Tag and finally choose the PRO Tag**.** *(Figure 4.13).*

When a view is tagged is going to be in the porduction folder, so this action must be taken only when the designer is completely sure of the viability of the view.

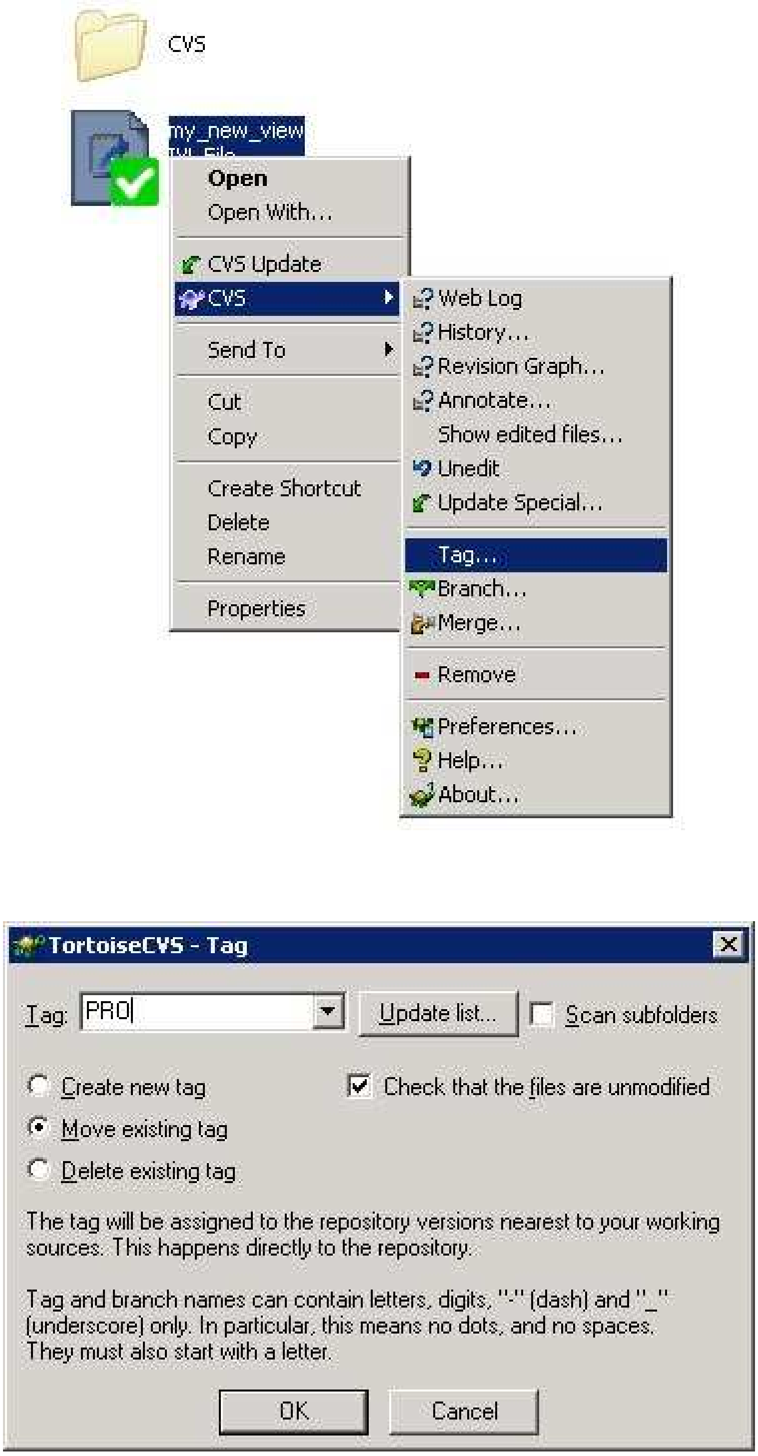

Figure 4.13: Tagging a view

Like TIM Views, TIM prototypes libraries are managed in CVS. When the TIM ViewComposer is started, prototype IVL files and Java code are automatically checked out to the C:\Documents and Settings\nice_login\tim-jviews-viewcomposer-symbols folder. The IVL files can be found in the src\ivl subdirectory, the Java source code in the src\java subdirectory. The Jviews Composer is configured in a way that it automatically saves new Java code to the correct directory (src\java). It is up to the user to make sure that changes to the IVL libraries are saved in src\ivl. *(Figure 4.14)*

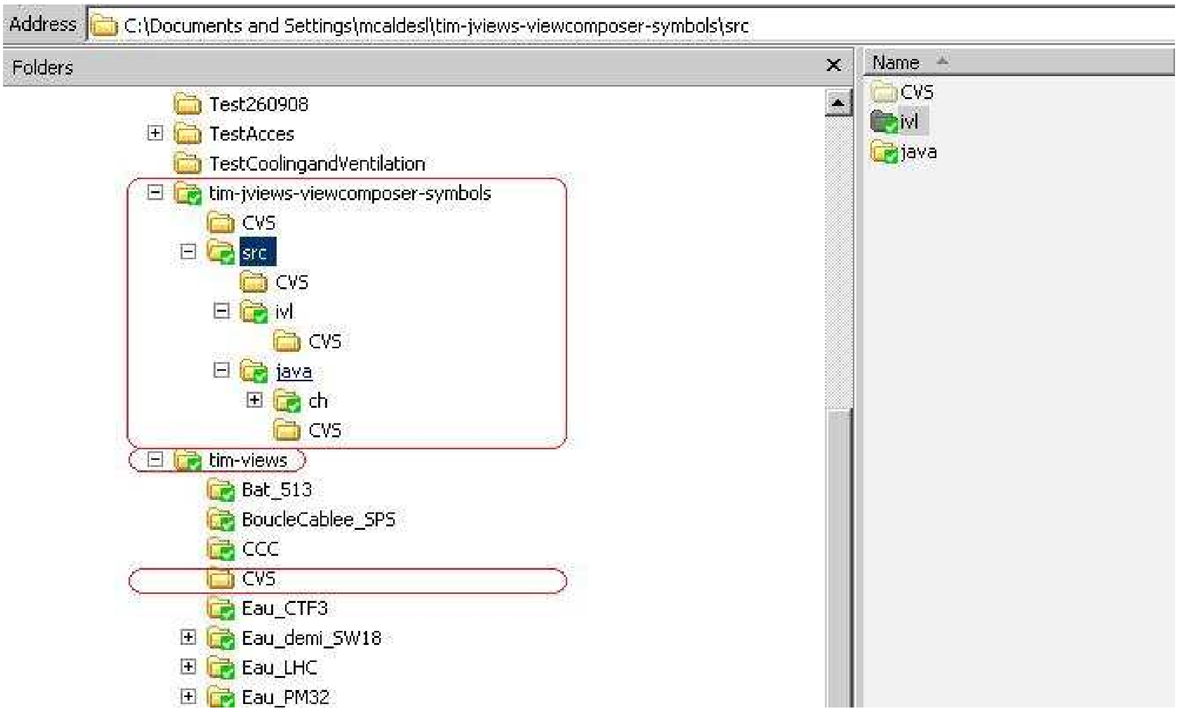

Figure 4.14: CVS folders

If a new Java prototype is created and added to one of the existing libraries (e.g. lib_cooling, lib_ther, lib_psccc, lib_process, lib_tools) is necessary to commit the modified library file (with the same procedure as TIM Views) and tag it with the **PRO** tag. If a new IVL library is created is necessary to add it into CVS, then commit and tag. After committing and tagging the IVL library files, they will be automatically redeployed on the TIM server within 10 minutes.

The src\java folder contains all Java prototypes classes used by the IVL libraries. If an existing class is modified, it should be noticed by the color of its icon (it would become red) This should be a signal, that this Java class needs to be committed. After committing the file it is also needed to tag it with the tag: **PRO**.

After commiting and tagging Java source files, they will automatically be recompiled and redeployed on the TIM server. Like with the views, the redeployment takes place every 10-15 minutes and is necessary to restart TIM Viewer before opening views using new prototypes.

5. Interfaces design for Cooling System in Point 8

The main objective of this project is to design the Synoptic Views for the supervision of Cooling and Ventilation Systems in Point 8. The maintenance of cooling and ventilation systems at LHC is controlled by PLC-systems and a local (SCADA) supervision system. Alarms are transmitted via an Ethernet communication network to central servers. Any failure on a piece of equipment is going to activate the correspondent alarm and this alarm is going to be displayed in Laser alarm screen and in the correspondent synoptic view.

We can structure the process in the next steps:

- MoDESTI Request
- Design of prototypes
- Design of synoptic views

5.1. Importance of the Synoptic Views

The LHC, in its 27 km of perimeter, is divided in 8 Points each one with a complicated structure of Cooling Systems and the Cooling System is only one of the Systems that the operators of TI have to keep it on. The have to keep on the electricity, ventilation, etc .

It's also important to consider that the operators of TI work with alarms and when an alarm is active the time that the operator takes to solve it can be really important to avoid failures of a big importance.

So, the design of the Synoptic Views for the Cooling System of the LHC has been considered from a long time ago. The Synoptics Views are not indispensable for solve the problem but they can be essential to know quickly the equipment where the alarms come from and to solve the problem to avoid failures in other equipments. Without these interfaces the operator only has the information displayed for LASER but this is only a text. LASER doesn't say which equipments are near the place where the alarm is active or which buildings can be affected for the alarm.

On the other hand, the design of these Synoptic Views takes a lot of time for the protocol that must be followed to insert all the DataTags in the System. But the global appreciation to design them is clearly positive.

For all these reasons was decided to develop this project to create a model to represent the Cooling Systems of all the Points of the LHC. Nowadays the synoptic Views of Point 8 are in operation mode and the interfaces for the other Points are going to be created in the next months using the model of Point 8.

5.2. Obtaining alarms and dates

The first step to design a synoptic view is obtaining all the alarms and information that this synoptic view is going to display. For that is necessary to follow the standard procedure used for TIM: The MoDESTI Request.

The data defining the alarm(s) or the data(s) information is entered on the standardised **Excel sheet** and then introduced on CERN's Electronic Data Management System (EDMS).

The database team takes care of the TIM Reference Database as well as the MoDESTI system for data integration.

The state of the MoDESTI can be consulted in EDMS. When the MoDESTI is closed is obtained an excel file *(Figure 5.1)* with all the information using SMILE. After that is necessary to filter the dataTags that are relevant to monitor the system and its state. It's also necessary define the colors and the levels of the alarms that are decided to display. These decisions are taken with the supervision of TI operators. [12]

GENERAL										LOCATION	
DESCRIPTION	DATA TYPE	EQUIPMENT		SYSTEM	SUB SYSTEM	EQUIPMENT SPECIALIST		ATTRIBUTE		SITE	BUILDING NUMBER
		GMAO CODE	Detail			ID	NAME				
bassin de rejet en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
bassin reservoir en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
tour ETR880 en mode automatique	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
tour ETR881 en mode automatique	Boolean	F$FSEP-02865	ETR881	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
tour ETR882 en mode automatique	Boolean	F$FSEP-02865	ETR882	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
tour ETR883 en mode automatique	Boolean	F$FSEP-02865	ETR883	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
tour ETR884 en mode automatique	Boolean	F$FSEP-02865	ETR884	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
filtre à sable en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
rechauffeur en mode automatique	Boolean	F$FSEP-02865		EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
Circuit SH8 en mode automatique	Boolean	F$FSEP-02865	SH8	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
Circuit SU8 en mode automatique	Boolean	F$FSEP-02865	SU8	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
Circuit UW85 en mode automatique	Boolean	F$FSEP-02865	UW85	EAU	Prim	19969	Gros.D	Mode_auto		L08	2865
Arret d'urgence enclenche	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Arret-urgence		L08	2865
Defaut sur onduleur	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Defaut		L08	2865
Onduleur en fonctionnement	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Fonct_onduleur		L08	2865
Presence tension 24V	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension		L08	2865
Presence tension 400V	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension		L08	2865
Presence tension 48V	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension		L08	2865
Presence Air Comprime	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_AC		L08	2865
Presence tension onduleur	Boolean	F$FSEP-02865	Elec.	EAU	Prim	19969	Gros.D	Presence_tension		L08	2865
Contacteur rechauffeur enclenche	Boolean	F$FSEP-02865	ERA887	EAU	Prim	19969	Gros.D	Contacteur_ON		L08	2865
Disjoncteur ferme	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Disj_Ferme		L08	2865
Disjoncteur ouvert	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Disj_Ouvert		L08	2865
Marche manuel disjoncteur	Boolean	F$FSEP-02865	ETR880	EAU	Prim	19969	Gros.D	Marche_Disj		L08	2865

	A	B	C	D	E	F	G
1					Tag information - General		
2							
3	POINT_ID	TIM_TAG_NAME	POINT_DATA	SYSTEM_NAME	SUBSYSTEM_NAME	GMAO_CODE	EQUIPMENT_NAME
4	100065	CM.L08.VGTCPOMPSF8:STATUS	String	COMM	TIM		VGTCPOMPSF8
5	107309	FB.L08.F$FSEP-02865_PTB8385:DEFAUT_GENERAL	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8385
6	107310	FB.L08.F$FSEP-02865_PTB8385:PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8385
7	107311	FB.L08.F$FSEP-02865_PTB8386:DEFAUT_GENERAL	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8386
8	107312	FB.L08.F$FSEP-02865_PTB8386:PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8386
9	107320	FB.L08.F$FSEP-02865_PTB8380:DEFAUT_GENERAL	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8380
10	107321	FB.L08.F$FSEP-02865_PTB8380:PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8380
11	107322	FB.L08.F$FSEP-02865_PTB8381:DEFAUT_GENERAL	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8381
12	107323	FB.L08.F$FSEP-02865_PTB8381:PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8381
13	107324	FB.L08.F$FSEP-02865_TT8302:TEMPERATURE	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_TT8302
14	107325	FB.L08.F$FSEP-02865_TT8303:TEMPERATURE	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_TT8303
15	107326	FB.L08.F$FSEP-02865_TT8301:TEMPERATURE	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_TT8301
16	107327	FB.L08.F$FSEP-02865_PTB8383:DEFAUT_GENERAL	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8383
17	107328	FB.L08.F$FSEP-02865_PTB8383:PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8383
18	107329	FB.L08.F$FSEP-02865_PTB8382:DEFAUT_GENERAL	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8382
19	107330	FB.L08.F$FSEP-02865_PTB8382:PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8382
20	107822	FB.L08.F$FSEP-02865_PTB8382:SEUIL_PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8382
21	107823	FB.L08.F$FSEP-02865_PTB8383:SEUIL_PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8383
22	107824	FB.L08.F$FSEP-02865_PTB8380:SEUIL_PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8380
23	107825	FB.L08.F$FSEP-02865_PTB8381:SEUIL_PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8381
24	107826	FB.L08.F$FSEP-02865_PTB8385:SEUIL_PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8385
25	107827	FB.L08.F$FSEP-02865_PTB8386:SEUIL_PRESSION	Float	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8386
26	107862	FB.L08.F$FSEP-02865_PTB8382:ETAT_PRESSION	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8382
27	107863	FB.L08.F$FSEP-02865_PTB8383:ETAT_PRESSION	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8383
28	107864	FB.L08.F$FSEP-02865_PTB8380:ETAT_PRESSION	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8380
29	107865	FB.L08.F$FSEP-02865_PTB8381:ETAT_PRESSION	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8381
30	107866	FB.L08.F$FSEP-02865_PTB8385:ETAT_PRESSION	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8385
31	107867	FB.L08.F$FSEP-02865_PTB8386:ETAT_PRESSION	Boolean	EAU	BRUTE	F$FSEP-02865	F$FSEP-02865_PTB8386

Figure 5.1: MoDESTI Excel sheet and Excel with DataTags

5.3. Prototypes Design

Before starting with the design of prototypes we have to decide:

- Which properties we are going to add in every prototype. For that we have to analize again the DataTags that we have obtained from the MoDESTY Request.
- The appearance of the prototype depending on its state. (Alarm active in red, normal state in green, etc)
- The shape of the prototype.

Once these points have been decided with the operators is possible to start drawing over prototypes with the JViews Composer.

5.3.1. Procedure

Using the tool of JViews Composer *Create a new prototype* is possible to create a new prototype following the next steps:

- Draw the shape of our prototype with the graphic tools of JViews Composer *(Figure 5.2)*

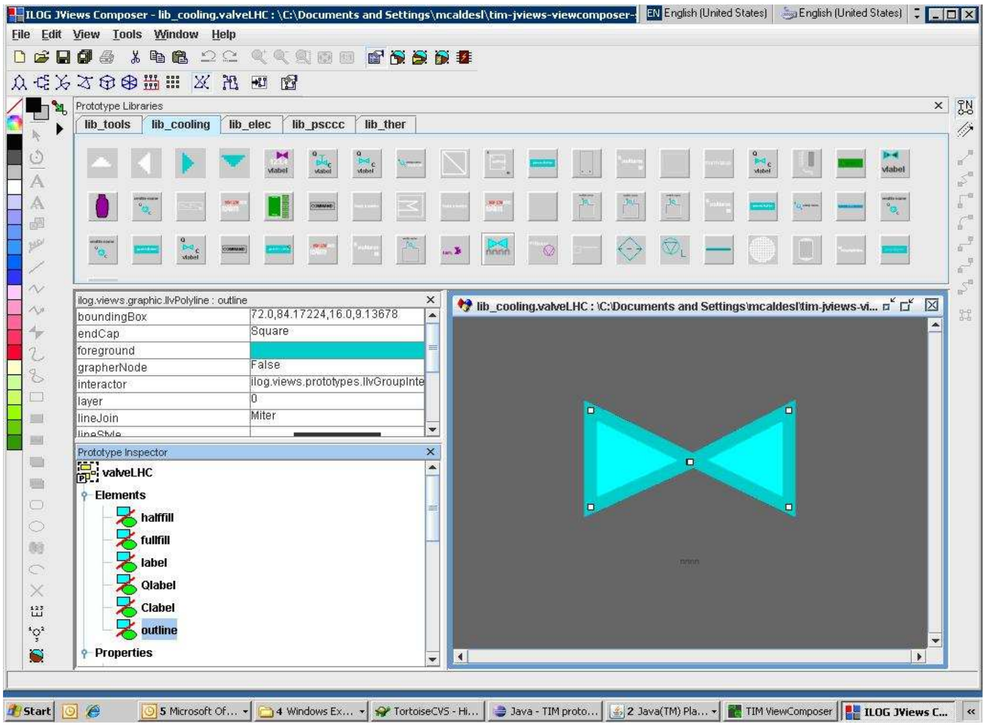

Figure 5.2: ValveLHC prototype

- Insert all the properties *(Figure 5.3).* These properties are going to appear as a white space to fill with a DataTag when the prototype is going to be used for a view.

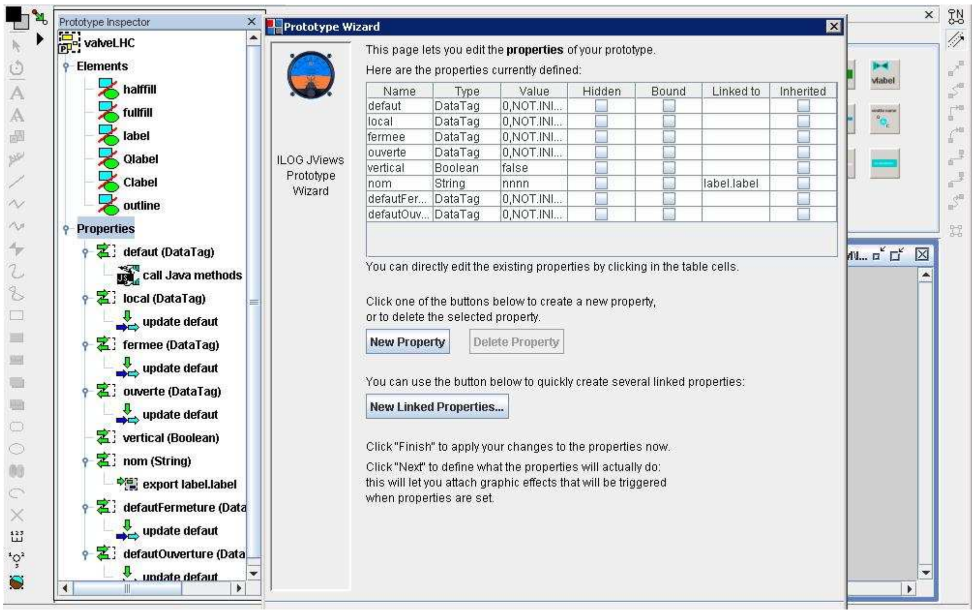

Figure 5.3: Properties of the prototype

- Writing the Java Code of our prototype (*Figure 5.4*)

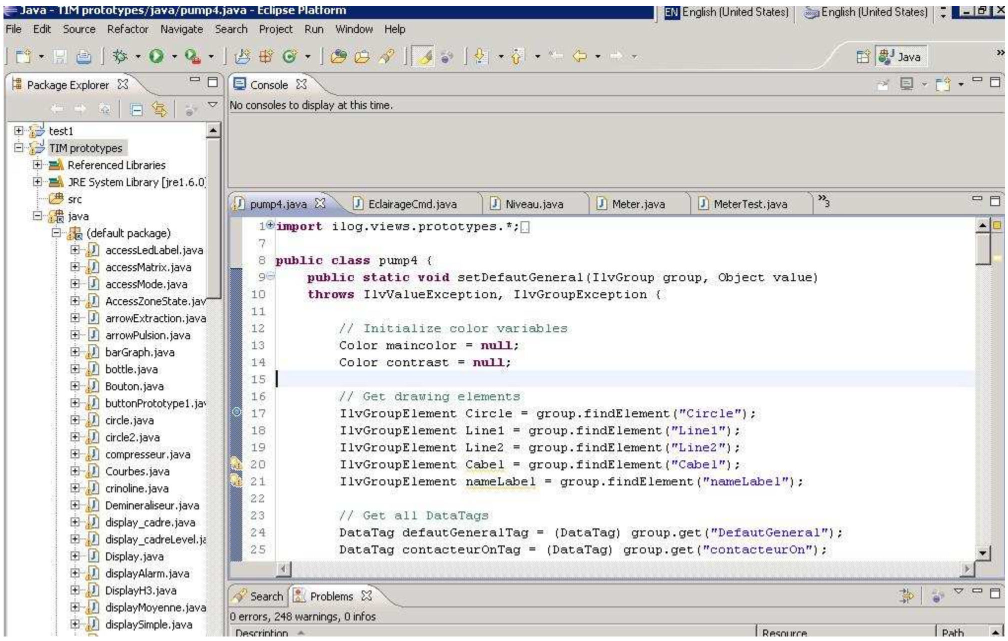

Figure 5.4: Java code

The Java code is usually written and compiled with Eclipse but it can be written and compiled directly from JViews Composer.

The new prototype is saved in a library and to make it available in TIM Viewer the Java code and the library have to be added (if is necessary) and commited in CVS how has been explained in chapter before.

5.3.2. Testing the prototype

Once the prototype is designed and implemented the next step is testing the Java code in the TimViewer to be sure that the Code of our prototype is not going to produce errors, In case of errors appears we have to revise, localize and correct the failure in the Java Code of the prototype.

The tool used to visualize the errors is a Java Console that appears automatically when the Tim Viewer is opened.

5.4. Prototypes

5.4.1. ValveLHC

This prototype is used to show the state of the valves. Seven properties are used to descript it.

The properties used for a general description of the valve are:

- ***nom:*** With this property we can know the name of the valve represented by the prototype.
- ***vertical:*** This property uses a Boolean to know the valve's position *(Figure 5.5)*. In case that the property is true the position is vertical. On the contrary the position is horizontal.

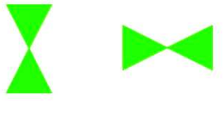

Figure 5.5: Valve's position

The properties used to descript the position opened/closed of the valve are:

- ***ouvert***
- ***fermee***

Both properties are Boolean DataTags and depending of their combination the valves can present different states. In the next table we can see the possible combination of the booleans and the correspond representation:

Ouvert	fermee	Figure
True	True	
True	False	
False	True	
False	False	

Table 5.1: Valve state

The properties to descript a failure in the valve are:

- ***defautOuverture:*** This property is true when there is a problem with the probe used to detect if the valve is opened.
- ***defautFermeture: :*** This property is true when there is a problem with the probe used to detect if the valve is closed.
- ***defaut***: This property appears in there is a general problem that produce a failure in the valve.

For more information about the Java code see *Appendix D.1*

In case that one or more of these properties are true the valve is going to appear as that: (*Figure 5.6):*

Figure 5.6: Valve with failure

5.4.2. PumpLHC

The PumpLHC prototype is used to show the state of the pumps in the water circuits. Thirteen properties are used to descript it.

The properties used for a general description of the pump are:

- ***nom:*** With this property we can know the name of the pump represented by the prototype.

There is only one property used to descript the position opened/closed of the pump:

- ***contacteurOn :*** In this property a boolean DataTag defines the state opened (true) or closed (false) . *(Figure 5.7)*

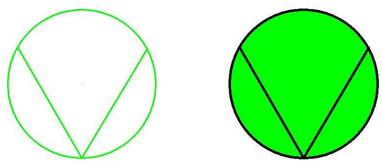

Figure 5.7: Closed/opened pump

In this prototype there are a lot of properties in reference to the kind of failure that can active the alarm in the pump. All these properties have been defined as a boolean DataTag and in all of them the alarm is active when the value of the boolean is true.

- ***defautGeneral***
- ***defautContacteur***
- ***defautPression***
- ***temperatureHauteBobinage***
- ***arretUrgence***
- ***defautTiroirPompe***
- ***tiroirPompeDebroche***
- ***defautDebit***
- ***defautFiltre***
- ***defautDemarreur***
- ***defautThermique***

If one or more of these alarms is active the pump is going to appear in red colour. *(Figure 5.8)*

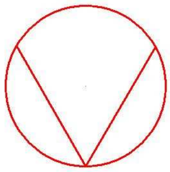

Figure 5.8: Pump with alarm activated

For more information about the Java code see *Appendix D.2*

5.4.3. Demineraliseur

This prototype represents the demineraliser and has been designed with two properties:

- ***nom:*** With this property we can know the name of the valve represented by the prototype.
- ***defaut:*** This property is a boolean that in case to be true indicates a failure in the demineraliser, in that case the demineraliser is going to appear in red colour. In case that the property defaut is false, the demineraliser will appear in green colour. *(Figure 5.9)*

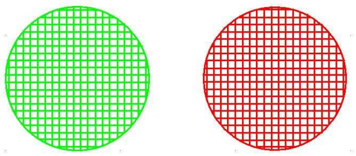

Figure 5.9: Demineraliser

For more information about the Java code see *Appendix D.3*

5.4.4. Filter

The prototype called filter has only one property to show if the filter is working correctly or not.

The property is called ***alarm*** and uses a Boolean DataTag to know if the filter has a problem, in that case the filter is going to be displayed in yellow colour. In case that the filter works normally is going to appear in green colour in the Tim Viewer. *(Figure 5.10)*

Figure 5.10: Filter

5.4.5. Ventilator

The Ventilator prototype is used to show the state of the ventilators used to refresh the water in the towers just at the beginning of circuits. Its shape is similar to pump prototype.

There is only one property used to descript the position open/closed of the ventilator:

- ***marcheVentil:*** In this property a boolean DataTag defines the state opened (true) or closed (false) of the pump. *(Figure 5.11)*

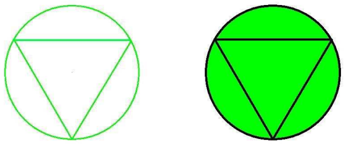

Figure 5.11: Closed/opened ventilator

In this prototype there is only one property to indicate a failure in the ventilator and the prototype is with the contour red in that case. Te property is **defautConvertisseur.**

For more information about the Java code see *Appendix D.6*

5.4.6. VaseLHC

This prototype is used to show the tanks of water and it works with six properties that are Booleans DataTags and whose activations means an alarm. Depending on the level of the alarm the colour of the water in tank changes.

- ***niveauBas :*** the level of the water is too low. This type of alarm is considered as a warning and the colour of the water changes to yellow.
- ***niveauHaut :*** the level of the water is too high. This type of alarm is considered as a real alarm and the colour of the water changes to red to indicate it.
- ***niveauTresBas:*** the level of the water is too low. This type of alarm is considered as a real alarm and the colour of the water changes to red to indicate it.

- ***pressionHaut*** : the pressure is too high.
- ***pressionBas*** : the pressure is tool low.
- ***defautControlFuite :*** This property indicate the probability of a leak in the tank.

There is another property to choose the colour of the water into the tank. This property is called **colour** and it is not a DataTag.

Figure 5.12: VaseLHC

For more information about the Java code see *Appendix D.5*

5.4.7. Niveau

This prototype is used to visualize the level of the water into the tanks and to see the alarms when the temperature of the water is too high or too low. The properties that we have are:

- ***level:*** This property use a float DataTag that contains a value for the water's level *(Figure 5.13)*. The high of the water in the prototype changes continually in proportional way to the different values of the level of the water. If the level increases the high of the water in the prototype grows up and if the level decreases the high goes down.
- ***alarmHigh:*** This property uses a boolean DataTag to know if the temperature of the water is too high. In case of true the color of the water changes from blue to yellow.

- ***alarmLow***: This property uses a boolean DataTag to know if the temperature of the water is too low . In case of true the color of the water changes from blue to yellow.

Figure 5.13: Niveau

For more information about the Java code see *Appendix D.7*

5.5. Colour code

Five colours are used to describe the state of the prototype.

The green colour is used to show a normal state of the prototype, it means that there is no alarm.

To describe an alarm the colours used are red or yellow depending on how important the alarm is. Red indicates real alarm and yellow colour describes a warning.

On the other hand, for defect the reference colour used in TIM to show a problem in the dataTag is blue or purple depending on the reason of the problem.

In case of a failure of communication the prototype is showed in blue colour. Usually this kind of problem occur for short periods of time.

In case that the problems come from an error in the DataTag as the code number or the definitions of the Data the prototype is going to appear in purple colour.

5.6. Cooling System Layout for LHC

The Synoptic Views are designed to show how cooling System of Point 8 looks like. In these section is explained the typical layout for the cooling systems depending on the type of water.

5.6.1. Primary Water

The primary water is supplied from the LHC cooling towers *(Figure 5.14)* and principally provides a heat sink for the following users:

- Cryogenic components, such as compressors, cold boxes etc.,
- The demineralised water circuits serving the underground areas,
- The condensers of chillers located in the surface buildings.

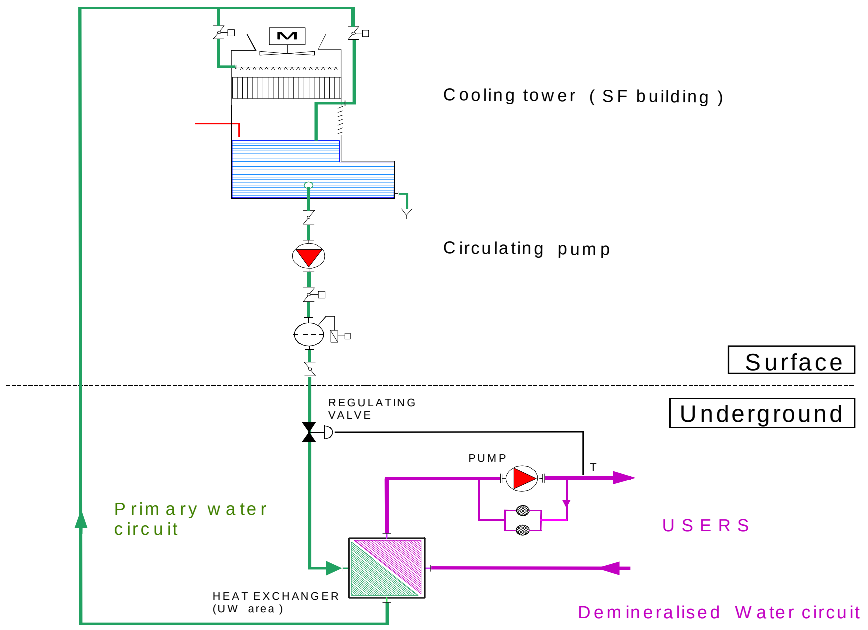

Figure 5.14: Primary water circuit

Each primary water loop is an open circuit. The water is cooled by cooling towers and distributed to users by pumps installed in pumping stations. The cooling towers are of an open atmospheric type, built as modular concrete structures, with each one having a cooling capacity of 10 MW. The pumping stations are directly attached to the cooling tower structure and are also constructed in reinforced concrete.

The choice of this structure was determined by the need to limit the noise to the environment in the neighbourhood around CERN. The water temperature of the primary water at the cooling tower has been set as follows:

Inlet	34 ºC (tolerance ±1 ºC)
Outlet	24 ºC

These figures, taken together with the normal atmospheric conditions in the Geneva area (maximum 21℃ wet bulb temperature and 32℃ outside temperature) corresponds to dimensioning data for the primary cooling system. The available pressure difference, on the user side is typically 3 bar.

Each pumping station is equipped with an auxiliary circuit for filtering the water in the basins. The filters are self cleaning and of the sand-bed variety. The circuit is also fitted with a heater and circulation pumps for frost protection.

Each distribution circuit is designed for two pumps; one in use and one as stand-by. For the first phase of LHC, the stand-by pump will not be installed, but some spare pumps will be stored at CERN, in order to limit the repair time to a maximum of two days in case of a breakdown. [13]

5.6.2. Demineralised water systems

Demineralised water is used in underground areas to cool:

- Power converters, cables, warm magnets and auxiliary equipment in the LHC tunnel (Machine circuit),
- The ATLAS, CMS, ALICE and LHC-B Experiments,
- The radio frequency system at point 4,

- The injection tunnels and magnets installed in TI 2 and TI 8.

Each demineralised water system is a closed circuit and equipped with a pump, heat exchanger, expansion vessel, filter, ion cartridge (demineraliser) and all the necessary control and regulating devices. This equipment is installed in the UW caverns at LHC Points 2, 4, 6 and 8. In the specific case of Point 8 the name of the cavern is UW85. The thermal load of the demineralised water network is extracted to the primary water system.

The main characteristics of the demineralised water system are as follows:

Inlet design temperature	27 ºC (tolerance ±1 ºC)
Set point	26 ºC
Design pressure	16 bar
Conductivity	<0.5 µS/cm

The layout of the machine circuit of the demineralised water is shown schematically in *(Figure 5.15).* From each UW-cavern, the demineralised water is distributed to the adjacent sectors of the machine. For example, the station in point 4 (UW 45) supplies water to sector 3-4 and to sector 4-5. Moreover, the transfer tunnel (warm magnets) TI 2, is supplied from point 2, while TI 8 is supplied from Point 8. [14]

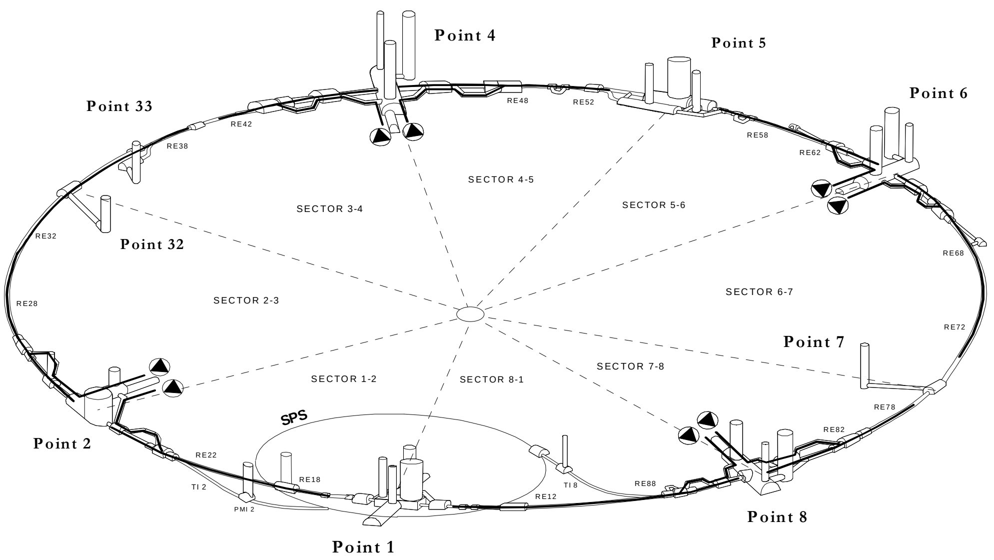

Figure 5.15: “Machine circuit “of demineralised water of LHC

5.6.3. Chilled and mixed water Systems

Chilled and mixed water are produced in the LHC surface buildings in water-chillers, using the primary water from the cooling towers as a cooling source. The chilled and mixed water is used in the LHC surface buildings in air handling units and in underground areas of UW and US in the heat exchangers. Chilled water is produced at the temperature of 5±0.5℃. Mixed water is produced at 13 ±0.5℃

5.6.4. Clean and waste water systems

The clean water is mainly ground water which comes from the stub tunnels, by infiltration through the tunnel walls and occasionally from leaking pipes. Such water is calcareous and may carry traces of hydrocarbons. It flows in the machine tunnel drain to a sump at the next lower LHC access point.

The waste water comes from lavatories (with waste grinders), urinals and wash basins. It is collected in sumps, diluted and pumped up to the surface, then discharged to the communal waste water network. In order to ensure that surface water does not leave the CERN sites carrying dirt and oil, water treatment plants have been installed. These include flocculation, neutralisation, settling and oil removing tanks/systems. Should a change in pH be detected, the electronic monitors trigger an alarm in the Technical Control Room.

5.7. Design in JViews Composer

To design the views on JViews Composer is firstly necessary to outline the plans with all the equipment and decide how many views are going to be used to represent the Point 8. . In our case waonsidered the design of three views as the minimum to display clearly all the information.

The general layout for the Cooling Systems is the one explained in the section before although is necessary the plans to know the reference names of the pumps, tanks, etc, and how many of them there are. These plans are in the CDD (Cern Drawing Directory) that is a multi-platform utility which manages engineering drawings made in any division at CERN.

In that plans appears each name of each part of the equipment and where it is located. The circuit is drawn using all the prototypes designed before.

5.7.1. Introducing information in the prototypes

The properties used to design the prototype become, when the prototype is used, white spaces to fill with the number of a DataTag or directly with a boolean, an integer, a float or a colour. *(Figure 5.16)*

It's important to note that if an incorrect type of DataTag is introduced in one property (e.g. Introduce a boolean DataTag instead of float DatTag) this fact is going to generate errors in the Java Console when the Tim Viewer will be opened.

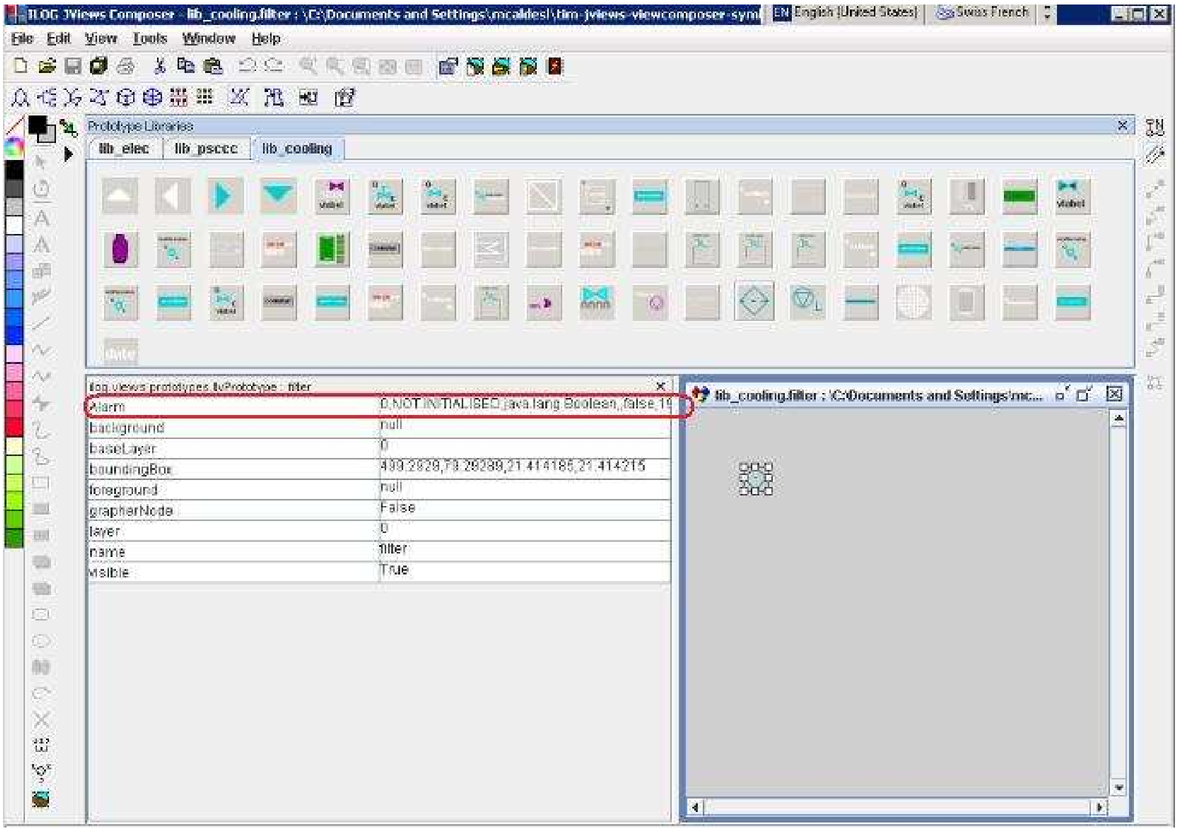

Figure 5.16: Views design

5.7.2. Adding the Views in Production

Once the views has been designed in JViews Composer and following CVS protocol, the views are firstly stored in *next folder* to test them in TimViewer and to create different versions if is necessary. And finally, when is sure that the views look like is wanted, the synoptic views are stored in Production.

In our case the designed Synoptic Views are three: SF8, UW85 and SU8. With this 3 interfaces all Cooling System for Point 8 is represented. In the next figures can be seen the final result for SF8 (*Figure 5.17*), for UW85 (*Figure 5.18)* and for SU8 (*Figure 5.19).*

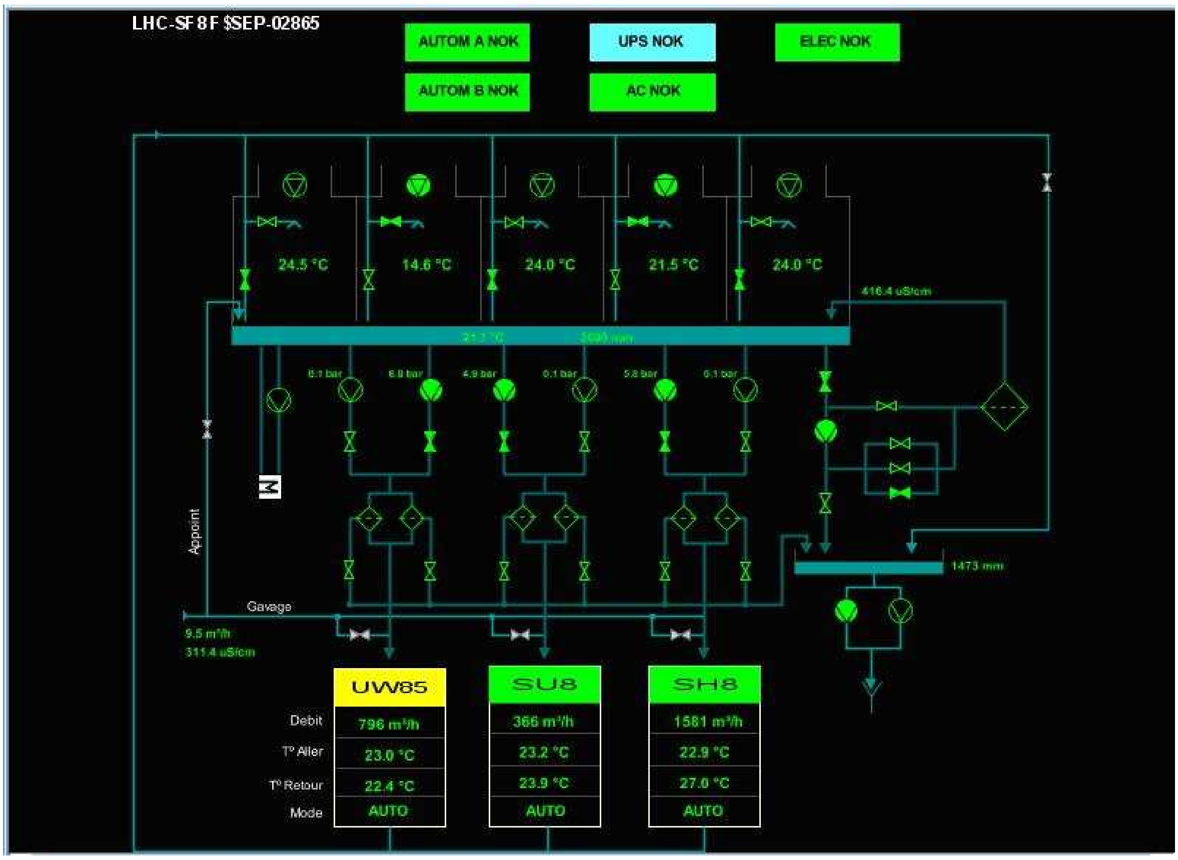

Figure 5.17: SF8 Synoptic View

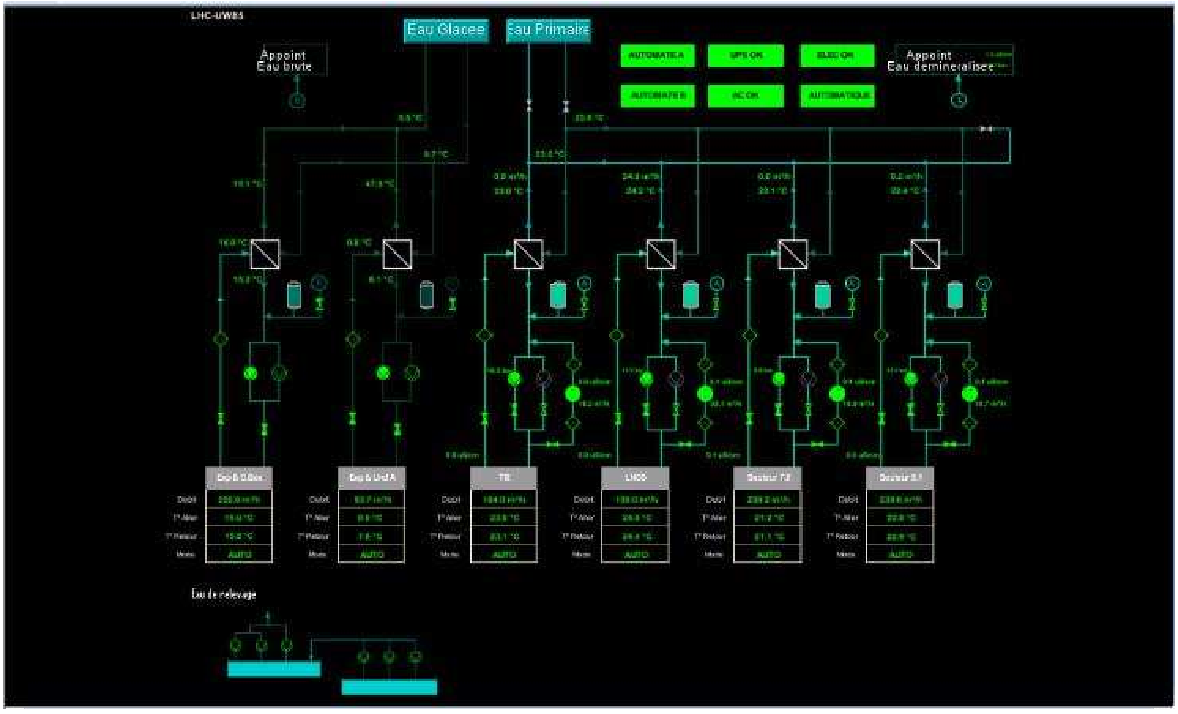

Figure 5.18:UW85 Synoptic View

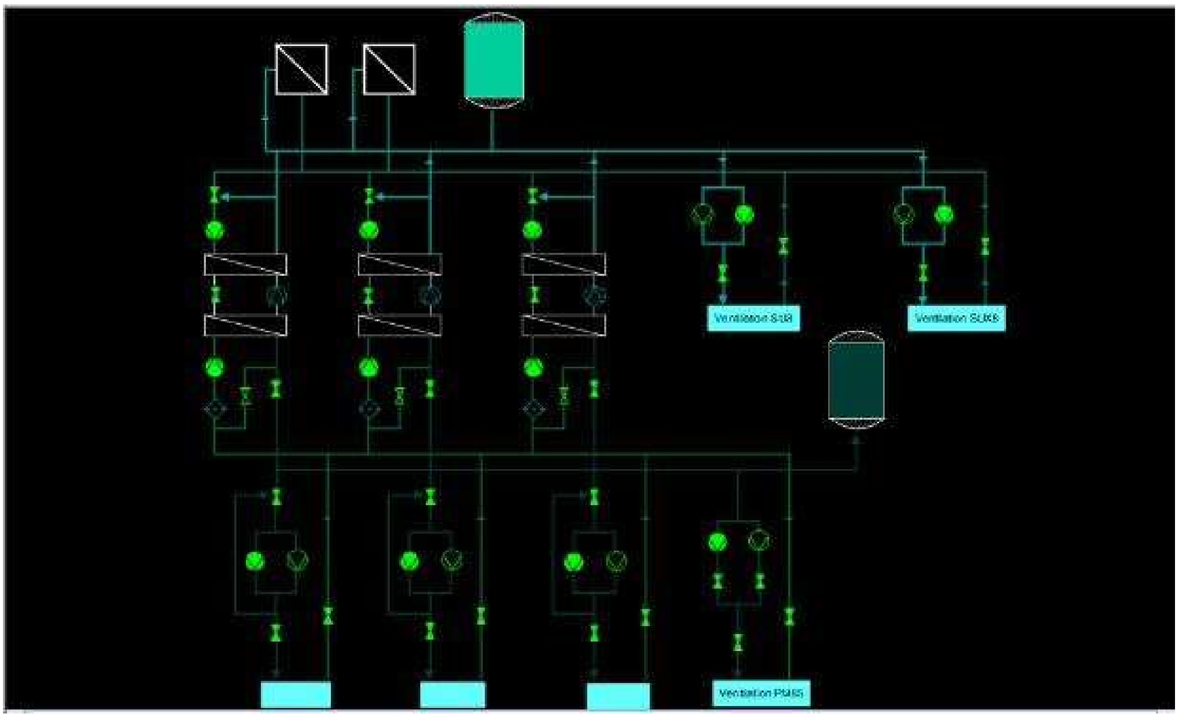

Figure 5.19: SU8 Synoptic View

These three Synoptics Views are going to be used as a reference for the design of the interfaces of all the Points of the LHC. All the prototypes are going to be re-used and, maybe it will be necessary to add some new one prototype depending of the new equipments that the new views are going to represent .

6. CERN and Environment

6.1. Environmental impact

To control the impact of its activities on the local environment, CERN carefully monitors the relevant parameters, which include everything from air and water quality to soil or agricultural products. This monitoring is administered by the Environmental Management System (EMS), developed and implemented with the basic aim to continuously improve CERN's environmental performance. EMS enables CERN to carry out and document its activities, conforming to environmental safety practices that are recognised worldwide.

6.1.1. Clean Air and Water

CERN produces atmospheric emissions from the ventilation of accelerator installations and heating and cooling equipment. CERN minimises these using filters and has built monitoring stations in the surrounding area to measure the resulting air quality. Rivers receiving CERN water are regularly checked for water quality.

6.1.2. Reducing Noise

Noise barriers are erected around civil-engineering worksites and CERN facilities of concern to minimize noise and levels are monitored continuously.

6.1.3. Recycling and sorting waste

CERN employs specialised companies to collect and transport special industrial and radioactive waste and follows Host States regulations in this matter. CERN is continuously improving the sorting and recycling of it conventional waste and strives to produce less on site.

6.1.4. Minimizing radiation

To study the composition of matter, CERN uses particle collisions that generate radiation. The levels of radiation emitted to the environment by the facilities at CERN are very low. Even when the next big accelerator, the LHC, is operating they will be less than a few percent of the natural radiation level. The major part of radioactive material at CERN is not contaminating. All radioactive material is handled following the regulations in force, in particular the very small amount of other radioactive material used temporarily in some experiments. CERN adheres to the internationally accepted radioprotection system in which the optimization of facilities and practices that aims at dose minimization is a natural obligation. With this system, the real radiological impact remains well below regulatory limits.

6.1.5. Preserving the landscape

To reduce the visual impact of new buildings on the landscape, plans are discussed with local authorities and CERN makes sure that additions to the existing landscape do not alter its overall appearance. Landscaping projects are adapted to each site with trees, bushes and grassy areas planted to ensure that the areas around the buildings remain indigenous to the area and natural.

6.1.6. Power and helium consumption

CERN consumes the greatest amount of electricity when its most powerful accelerator, the LHC, is running. This amounts to 120 MW for the LHC (out of 230 MW for all CERN) which corresponds more or less to the power consumption for households in the Canton (State) of Geneva. Assuming an average of 270 working days for the accelerator, the estimated yearly energy consumption of the LHC in 2009 is just over 800 000 MWh. This includes the site base-load and the experiments.

A large fraction of the LHC electrical consumption is to keep the superconducting magnet system at their operating temperatures (-271.4℃ or -268.7℃ depending on the magnets). Thanks to the superconducting technology employed for its magnets, the nominal consumption of the LHC is not much higher than that of the Super Proton Synchrotron (SPS), even though the LHC is much larger and higher in energy.

The magnets are cooled using liquid helium. The exact amount of helium lost during operation of the LHC is not yet known. The actual value will depend on many factors, such as how often there are power cuts and other problems. What is well known is how much will be needed to cool down the LHC and fill it for first operation. This amount is around 120 tones.

6.2. . Radiation at CERN

6.2.1. Is CERN a nuclear laboratory?

CERN, the European Organization for Nuclear Research, is a laboratory that studies particles and their interactions, but is not concerned with nuclear energy or weaponry.

The name is derived from European Council for Nuclear Research, a provisional body founded in 1952 with the mandate of establishing a world-class fundamental physics research organization in Europe. At that time, pure physics research concentrated on understanding the inside of the atomic nucleus and the word ‘nuclear’ in the name reflects this. Very soon, the work at the laboratory went beyond the study of the atomic nucleus and onto sub-nuclear particles and their interactions. As a consequence, the laboratory operated by CERN is commonly referred to as the “European laboratory for particle physics” (“Laboratoire européen pour la physique des particules’) and it is this latter title that really describes the current work of the Organization.

6.2.2. Ionizing radiation

Radiation is the transport of energy through particles or waves, such as X-rays. It occurs, for example, when an unstable atom breaks down to form a stable atom, and releases some of its energy. Rocks, the sun and space all naturally emit ionizing radiation that we can detect on Earth. Artificial ionizing radiation also comes from medical treatment or in small amounts through mining and nuclear power industries. Though safe in small doses, in high doses ionizing radiation can be dangerous as the energy can knock electrons off atoms in living bodies, ionizing and damaging them. The ionizing radiation dose is usually measured in Sieverts (Sv), which is a measure of the effect of radiation on the body.

CERN’s experiments involve colliding beams of particles together or into a stationary target. When this happens some of the particles release radiation or new particles are created. This is very different to radiation from a nuclear power plant where without human intervention the radiation levels could increase exponentially. At CERN radiation only occurs when the particle beam is on, and turning it off stops emissions immediately. Collision events are also very rare; at the LHC each day only 2 nanograms (one millionth of a milligram) of protons will be accelerated and only a small proportion of these will collide. The proton beams can circulate for hours in the collider without being spent totally. It would in fact take millions years to collide 1 gram of protons. Radiation sometimes activates some pieces of components surrounding the collision points, causing them to become radioactive. This small amount of material is well confined and when the accelerator is dismantled it is handled following the appropriate regulations.

6.2.3. Amount of ionizing radiation produced at Cern

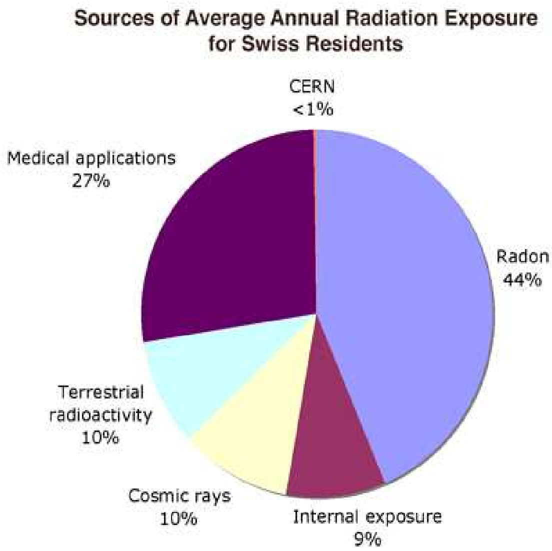

Figure 6.1: Annual Radiation Exposure for Swiss

CERN typically delivers about 0.01 mSv of effective dose of radiation to someone residing in the local area per year. This is less than 1% of the total annual dose of 3.7 mSv that individuals already receive on average, both naturally, through radioactive elements in soil and rocks or cosmic rays, and artificially through medical procedures, for example, as shown in the chart below. To put this into context, a year of living near CERN is the radiation equivalent of the increased cosmic ray exposure experienced whilst taking a return flight from Geneva to Athens.

This additional radiation dose from CERN is also lower than natural differences between different areas, so that moving to another municipality could raise your annual radiation dose to much more than living near CERN. The Swiss Office Fédéral de la Santé Publique (OFSP) and the French Institut de radioprotection et de sûreté nucléaire (IRSN) have stated that compared with these natural fluctuations, the effect of CERN radiation on the public is negligible.

6.2.4. Radiation monitored and controlled

CERN adheres to an internationally recognised radioprotection system that always strives to minimize radiation exposure and, as a consequence, CERN's emissions remain well below regulatory limits. To check this, 200 various on-line monitoring stations are spread throughout the site and its surroundings, including sensitive gate monitors that measure the radioactivity of each item leaving and entering the site with alarms that prevent any uncontrolled release of radioactive material from CERN to the outside world. Teams of the CERN Safety Commission also take samples of ambient air, soil, river water, groundwater, rainwater, vegetation and agricultural products from the surrounding environment, and carry out thousands of analyses on the samples per year.

The limits CERN imposes on exposure of staff and visitors are derived from EU law and all members of personnel working in sensitive areas wear dosimeters that measure their exposure. Shielding is in place throughout the radioactive elements on the site. The fact that accelerator facilities are underground provides an additional natural barrier. Where radioactive materials are stored it is done following the appropriate regulations. CERN teams carry out computer simulations of radiation fields for existing and planned facilities, such as the LHC, so we can anticipate any problems ahead of time. In this way we are able to predict and minimize environmental impacts before the construction of any facility.

Recently, the impact studies for the LHC, Super Proton Synchrotron and the CERN Neutrinos To Gran Sasso facility were successfully reviewed by French and Swiss radioprotection government professionals. Of course, we monitor the real levels once programmes go live. The start up of the LHC has not supposed to significantly increase the levels of the radiation exposure of the public and the resulting effective doses will stay close to the current levels.

6.2.5. Radiation effects on the environment

The radioprotection authorities in the CERN host states, the Swiss Office Fédéral de la Santé Publique (OFSP) and the French Autorité de Sûreté Nucléaire (ASN) supported by the Institut de radioprotection et de sûreté nucléaire (IRSN), have carried out a 'Point

Zero' study aimed at assessing the state of the environment around CERN before the LHC start-up.

Based on results obtained over two years, the study report concludes that the radiological impact of CERN on the local environment over its 53 years of activity is negligible. The results of this study also provide a reference point for the future monitoring by the Host States' authorities to confirm that the public exposure always stays below safe levels. The OFSP and IRSN surveyed the CERN environment in the past and will continue to survey it throughout the operation phase of the LHC. Consequently, the "Point Zero" study was only a start of an international monitoring programme dedicated to the Large Hadron Collider.

7. Cost of the project

The cost of this project is expressed in terms of the cost of the work done by myself in a period of 15 months, 13 months working at CERN and 2 months typing the project (the period of one of this months is considered in the period working at Cern, in hours out of working). In the calculation it has been assumed a working week of 40 hours distributed in 5 working days of 8 hours. During the period of June-October the working day had to divide to attend to other projects, due to this, the working day during these months it was reduced at 20 weekly hours. *(Table 7.1)*

Period	Working day	Days	Hours
December-May (2007-2008)	Complete (8 hours)	106	848
June-Setember (2008)	Half (4 hours)	87	348
October-December (2008)	Complete (8 hours)	58	464
	TOTAL	**251**	**1660**

Table 7.1: Hours working at Cern in the project

To calculate the personnel costs (*Table 7.2*) has been supposed a salary as junior engineer of 15€/h:

Hours	Salary (€/h)	Personnel Costs (€)
1660	15	**24.900**

Table 7.2: Personnel Costs of the project

During the period the project some courses have been taken at Cern, two courses for learning French and another course to learn how JViews Composer works. These courses and the typing period of the project has been considered as Other Costs (*Table 7.3)*

Work	Hours	€/h	€
French Course	180	10	1800
Course for Jviews Composer	40	12	480
Typing	180	10	1800
	TOTAL		**4.080**

Table 7.3: Other Costs

Taking into account everything before detailed, the total cost of the project is *(Table 7.4):*

Concept	Cost(€)
Work at Cern	24900
Training Courses	2280
Typing	1800
TOTAL	**28.890 €**

Table 7.4: Total Cost of the project

8. Acknowledgements

First of all, I would like to thank Peter Sollander, my supervisor at Cern for giving me the opportunity to develop my thesis in his group. Thanks also to my supervisor in UPC, Dr. Emilio Hernandez, for all the support and his willingness to help.

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9. Conclusions

In this project has been created the Synoptic Views used to monitor the Cooling Systems of Point 8 in the LHC.

The new Synoptic Views fulfill all the requirements that had been imposed at the beginning of the project:

- Creation of re-usable prototypes that represents the pumps, valves, filters and all the equipment that can be found in the Cooling Systems of all the Points of the LHC. These prototypes are going to be used in next months to design all the Synoptic Views of Cooling Systems in LHC.

- Creation of clear Views to make lighter the job of the operators due to they can use the Views as a support of LASER information.

- All the views have been designed with the support of TI operators and their opinion has been always essential for all the decisions that have been taken in reference to how the prototypes have to display the information (colour of the alarms, shape of the prototypes, etc.).

This project was finished on December of 2008 with the starting up of the Synoptic Views for Point 8 into the operation mode. Although the real achievement of the project is the fact that the Synoptic Views are going to be used as a model for all the Cooling System in LHC and all the prototypes created will be re-used without the requirement to design new prototypes.

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