

Measurement and Quality Assurance of a New Generation of Particle Accelerator

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Abstract. CERN is building the most powerful particle accelerator in the world to discover more of the secrets of matter. To reach this objective, the required magnets and detectors must be manufacture at a very high level of precision. But this is not so easy as it seems to be.

1. Introduction

The Large Hadron¹ Collider (LHC) project at CERN is a new generation of particle accelerator, which brings protons and ions into head-on collisions at a very high energy level. It can collide proton beams with energies around 7-on-7 TeV² or for heavy ions such as lead with total collision energy in excess of 1250 TeV, which will be unique on the world. This will allow scientists to determine the structure of matter and recreate the conditions prevailing in the early universe, just after the so-called "Big Bang" [1].

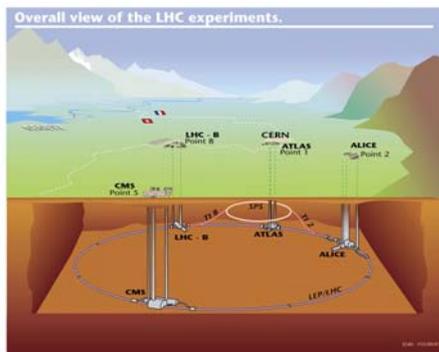


Fig. 1. Overview of CERN

The accelerator is built astride the Franco-Swiss border west of Geneva (the commissioning date of the LHC is foreseen for 2007/08 [2]), at the foot of the Jura Mountains. It is designed to share the existing LEP tunnel, which has a diameter of 9 kilometres.

A modern accelerator or collider is a huge investment, which must remain a useful research tool for a long time, and therefore should be adaptable to emerging needs.

The technical choices made in the LHC to deliver high performance while minimizing cost could drastically reduce the adaptability of the machine, since most of its elements are closely packed and embedded in a continuous cryostat [3].

This is necessary because the LHC superconducting magnets will sit in a 1,9 K bath of super fluid helium at atmospheric pressure. It uses super fluid helium, because of its unusually efficient heat transfer properties, allowing kilowatts of refrigeration to be transported over more than 1 kilometre with a temperature drop of less than 0,1 K. This bath will be cooled by low-pressure

¹ Hadron = nuclear particle which consists only of Quarks - like Proton, Neutron and Meson.

² TeV = Tera electron volts = 10^{12} eV, 1 eV = $1.602176462 \cdot 10^{-19}$ J; The unit eV is used by physicist to express the amount of energy at the level of the atomic scale.

liquid helium flowing in heat exchanger tubes threaded along the string of the magnets. The reliability and efficacy of this sophisticated cryoloop are key factors in achieving the required high magnet field performance.

In all, LHC cryogenics will need 40.000 leak-tight pipe junctions, 12 million litres of liquid nitrogen will be vaporised during the initial cool down of 31.000 tons of material and the total inventory of liquid helium will be 700.000 litres [4].

2. Area of Subject

To accelerate the particles nearly to the speed of light and keep them on their track around the circle, 1232 superconducting magnets are needed to lead the particles with their magnet field around the 27 km long course.

Each of these magnets is about 15 m long (see Fig. 2).

Through the cooling down of a magnet from room temperature ($\sim 20\text{ }^{\circ}\text{C} = 293,15\text{ K}$) to 1,9 K, the 15 m long magnet shrink about 45 mm (or 3 mm per 1 m).



Fig. 2. Testing area



The contraction of the body was simulated with a Finite Element (FE-) software, but due to reason that these magnets have not a uniform body (a iron yoke and a special alloy for the coils, which make the superconductivity possible), the warping is different over the cross section of the body.

Fig. 3. Cross section of the magnet

For the physicists it is important to know the deformation of the magnet, because the warp of the yoke influences the shape of the magnet field inside the magnet. This can cause an inefficiency on the beam energy, because the magnet field “guides” the particles around the ring.

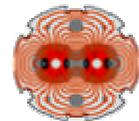


Fig. 4. Magnet field

Also the joint connection between all the magnets should fit at room temperature as well as at the 1,9 K. Also the unsteadiness during the manufacturing and assembling process has an influence on the deformation while the cooling down process. It is not so easy to measure the contraction of the magnet, because the magnet is covered with the cryostat vessel, where the magnet is cold down till to the working temperature of 1,9 K. The measurement is performed with a laser interferometer. The required mirrors will be attached on the magnet, before it will enter the vessel. In the vessel itself exist special openings, where the optical interface of the interferometer is plugged in.

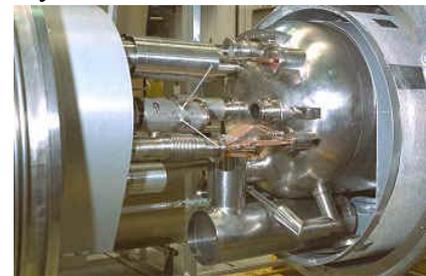


Fig. 5. Joint connection

To create these FE-models, it is necessary, that 3D-models are created from all components. Also a lot of data from the material constants are necessary. The models are made with CAD system (CAD= Computer Aided Design).

That is the reason, while all mechanical engineering and installation drawings for the LHC project are made with a Computer Aided Design (CAD) software.

CERN is using 4 different CAD systems:

- for 3D and 2D drawings: EUCLID, RobCAD and Pro-Engineer,
- for 2D drawings: AutoCAD 2000.

In the collaborations with CERN are also used the CAD applications AutoCAD 14, CATIA and Solid Works.

All engineering drawings referenced in a CERN contractual document shall incorporate the appropriate CERN title block. The drawing title and the parts lists shall be written in English only or in English and French. All engineering drawings shall be stored in the CERN Drawing Directory (CDD), which is a database with an Internet interface. The drawings should have the relevant descriptive information and identification by a unique drawing number [5].

All the engineering drawings are submitted to a review and approval process before being released [6]. If there must be created new revisions of released drawings are submitted to the same review and approval process as the original drawing.

3. Results

Not all of the needed parts for the new collider and the 4 new detectors are developed at CERN. Many parts are developed and built by institutes and industries all over the world (Europe, Russia, USA, Canada, China and India).

There exist a CERN intern standard for drawing rules, which applies also to the involved collaborations, but only a few departments at CERN and even less outside follow these internal standards [7].

The result is, that you get a hole punch of layers (each layer has a dedicated colour) on the screen, where it is difficult to know what is what. From drawing to drawing you have to switch between the meanings of the layers/colours.

So, if an engineer wants to implement a part from a “foreign” standard drawing in his drawing, the problems start – even they are working with the same software. Of course, the problems will increase dramatically, if the drawings were made on different systems than the own one. Because the interface between each CAD software is rather bad. And the only standard, which nearly all applications know for file transferring, the *.dxf-format, transports not all the information.

For the mechanical engineering drawings exist since many of year’s well known ISO standards, like for:

- Letter ISO 3098-0 (1998-04)
- Line type and line type scale ISO 128-20 (1997-12)
- Line thickness ISO 128-20 (1997-12)
- Title block ISO 7200 (1970-12)
- Part list ISO 7573 (1987-02)

But it seems to me, that these standards have nearly no meaning, if we reach the area of CAD software instead of the “old fashioned” ink drawings, where these standards were accepted quite well.

At the moment, many designers at CERN “translate” the foreign drawings on their own standard, before they start working on it.

Also the “never ending story” of the two existing projection methods (ISO 5456-1 & ISO 5456-2 (1998-04)) between

- Method 1, also called method E (used in central European) and
- Method 2, also called method A (used in USA & GB)

cause big troubles in the manufacturing and assembling of the ordered parts. In the past 5 years, the costs for CERN for errors caused on this problem had a value of more than 80.000 Euro of material cost.

4. Concluding Remarks:

In the time of globalisation and ISO standards, it should be possible to develop a uniform CAD format over all platforms for drawings made with a CAD – system, which supports all functions of the drawings (like the associative dimensions and hatches, one-to-one acceptance of layers, text formats and blocks like they were created by the designers, ...).

That this objective is possible to reach shows us the example of the HTML format (Hyper Text Markup Language), which is the standard format for text publications on the Internet. The reason for this is, that HTML is well accepted by all operating systems and every software producers.

List of Reference

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