SLHC-PP

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History of Changes

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1.0	07/03/11	Creation	D. Reynet – S. Russenschuck - L. Williams

The Preparatory Phase of the Large Hadron Collider upgrade (SLHC-PP) is a project co-funded by the European Commission in its 7th Framework Programme under the Grant Agreement n° 212114. SLHC-PP began in April 2008 and will run for 3 years.

TABLE DES MATIERES

1. EXCECUTIVE SUMMARY

The beam optics of the triplet phase 1 upgrade requires a chain of superconducting accelerator magnets with a cryostat arrangement different to that of the triplet chain in operation in LHC today. The cryostats of the existing triplet chain cannot therefore be reused. This leads to the need for a new cryostat for each of the magnets (5 in total) in the phase 1 upgrade chain.

The existing triplet chains comprise the innermost machine elements; those that are installed to the left and right hand sides of the interaction points 1 (ATLAS) and 5 (CMS), which are particularly congested zones of the LHC.

This report summarizes studies of the triplet phase 1 upgrade cryostats conducted by CNRS/IN2P3 within the framework of WP-6 of SLHC-PP. As the new inner triplet quadrupole magnets are in size and weight comparable to the main LHC dipole magnets, the cryomagnet assembly can be carried out on dipole assembly tooling, suitably modified but maintained backwards compatible.

2. INTRODUCTION

The phase 1 upgrade triplet magnet chains must be installed in the volume left vacant once the existing equipment is removed.

Since the triplet chain is an extension of the LHC machine, which needs to be connected to machine elements upstream, and since there is no transverse free space in the congested zones around interaction points 1 and 5 of the LHC, the transverse overall dimensions of the triplet phase 1 upgrade cryostats are constrained to those dimensions of the LHC main ring magnets.

This leads to a number of technical consequences and opens areas where the resources required for the project could be reduced:

- The cryo-magnet assembly benches in operation at CERN may be used after some modifications for the assembly of the triplet phase 1 upgrade cold masses into their cryostats.
- The cryogenic test benches in operation at CERN may be used, with minimal modification to carry out performance testing of the triplet phase 1 upgrade magnets.
- The equipment required to transport LHC magnets underground and to install them in their final position in the LHC, might be used with minimal modification to handle the triplet phase 1 upgrade magnets.

It has been shown that, without significant compromise to their performance, the outer diameter of the triplet phase 1 upgrade quadrupole magnets could be constrained to 580 mm, that of the LHC main ring magnets.

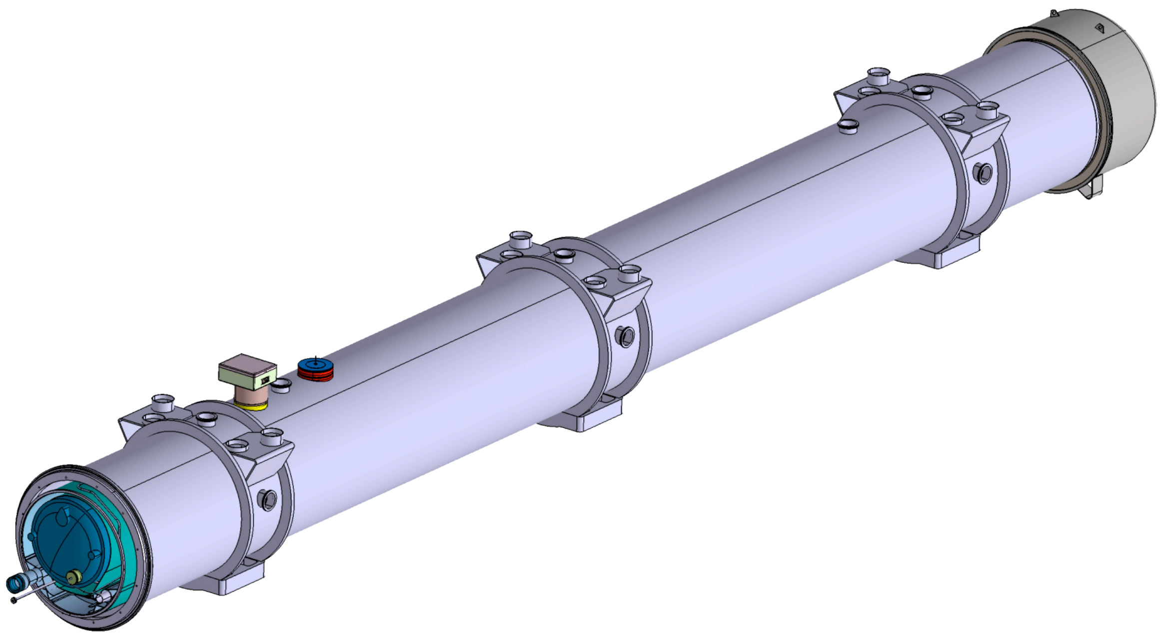
Further significant reductions in the resources required for the project could be obtained through the decision to base the design of the triplet phase 1 upgrade cryostats very closely on the LHC main ring dipole cryostats design.

Wherever possible this philosophy has been further extended to permit the use of standard LHC cryostat components in the triplet phase 1 upgrade cryostats.

- Some components could be sourced directly from the stock of LHC spare parts purchased at advantageous large series prices.
- Thermal performance analysis and testing of the cryostats for the triplet phase 1 upgrade is not required since accurate data may be easily derived from the measured performance of LHC main ring cryostats.

The design of the prototype cryostat, largely based on the reuse of LHC machine components is described in section 1. Taking advantage of this standardization, the existing cryo-magnet tools have been modified and adapted to the characteristics of this prototype cryostat. These actions are detailed in section 2.

3. STUDY OF THE CRYOSTAT PROTOTYPE



All-together 32 person months of design work have been invested in the prototype design of the cryostat needed for the Q1 type magnet of the triplet phase 1 upgrade chain. A design file containing all drawings detailing this prototype cryostat design is available.

The design analysis is contained in 7 technical notes and 6 calculation files (finite element analysis and calculations according to the CODAP construction code).

Technical specifications have been produced for the industrial production of a prototype cryostat of the Q1 type, and a market survey to identify competent European suppliers has been carried out.

The design of the prototype cryostat was conducted on the basis of a dipole type vacuum enclosure. The enclosure was designed so that it can be installed on both the left and right-hand sides of the interaction points 1 and 5 of the LHC. The design of this vacuum enclosure has been validated by CODAP and FEM calculations. The vacuum enclosure, with a thickness of 12 mm, and the reinforcement rings, all in carbon steel, are identical to those of the dipoles.

Based on the dipole design, the support modules have been enlarged to conform to the support jack position of the current triplets. All the plugs, sliding supports, and bearings, are of the standards dipole types. The fixed support is situated at mid-length, and its design takes features from the LHC dipole and the stand along quadrupole type, hereafter referred to as SSS-MS.

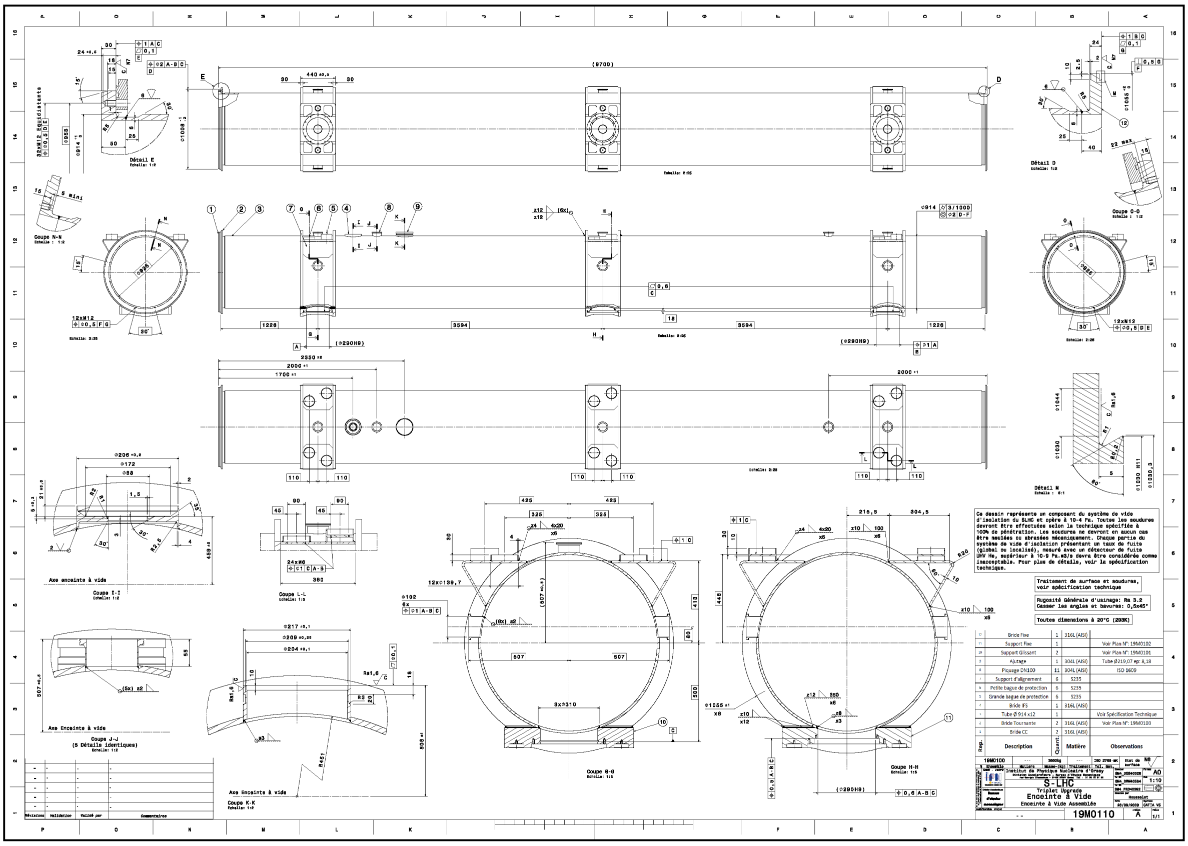
The interaction-point (IP) end-flange is an LHC standard type and allows the mounting of LHC type dished ends to ensure the interface with the standard interconnection. The non-IP end is furnished with a fixed flange and a mobile flange that allows retraction of the bellows as in the standard LHC interconnection.

The standard LHC dipole safety valve has been integrated in a vertical position at the non-IP end. A DN100 flange and the IFS connection box are located in this same area, to make space for the retraction of the interconnection bellows.

The alignment target supports have been placed further apart and duplicated, to comply with existing alignment and measurement interfaces and systems, and to ensure the same vessel may be installed either to the left or the right of the IP. Six DN100 access ports were inserted, three on the cold mass' vertical axis and three on the cold mass' horizontal axis, in order to allow the installation of sensors for the monitoring of cold mass movements with respect to the vacuum vessel.

The thermal shielding with multi-layer insulation (MLI) and its cooling circuits at 80 K have been adapted to the length of the MQXC magnet. Extruded profiles containing the cryogenic line-E, equipped with bi-metallic aluminium-to-stainless-steel transitions and the screen at 80 K are derived from the LHC standard types. They were adapted to the length of the magnet MQXC taking into account the differential thermal contraction.

The three epoxy-fibreglass reinforced plastic (EGFRP) support posts are identical to those of the LHC dipole. The 4 K and 80 K heat-intercept plates were positioned such as to respect the interconnection interfaces.



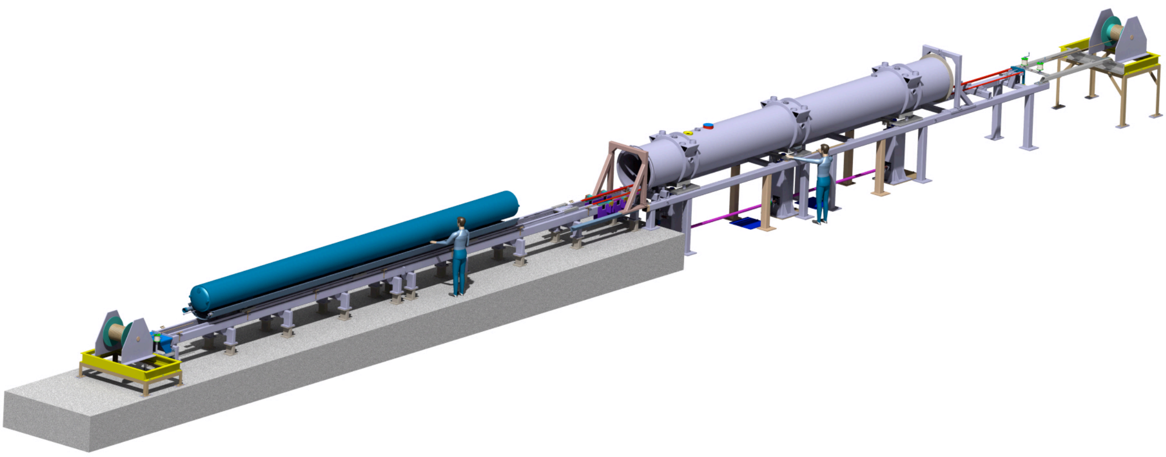
4. STUDY OF ASSEMBLY TOOLS

All-together 14 person months of design work have been invested in the modification of the SSS-MS tooling to perform assembly and disassembly of the cryo-magnets Q1, Q2A, Q2B and Q3 of the triplet phase 1 upgrade chains. A design file containing more than 100 engineering drawings detailing the modifications that are required to the SSS-MS tooling is available.

Technical procedures have been produced to accompany these drawings; they describe the methods and modification for the installation of the assembly tooling.

As the new inner triplet quadrupole magnets are in size and weight comparable to the main LHC dipole magnets, the cryomagnet assembly can be carried out on dipole assembly tooling, suitably modified but maintained backwards compatible. This equipment is dimensioned for loads of 2 tonnes per metre over a length of 12 m. A dipole type assembly table is adapted to be coupled with the cryostat integration table used for the SSS-MS. The cold mass will be equipped on the dipole “dressing table”. The fully equipped cold mass is then introduced by means of rails and sledges used for SSS-MS. The table and lifting columns, allowing the cold mass to be locked in its enclosure are also adaptations of the SSS-MS table.

The present study allowed improvements on existing tooling benefiting from experience on the cryostat integration and the removal of the damaged dipole cold-masses after the LHC incident. The main developments, apart from the differences in lengths and management of interfaces, concern the implementation of two chassis supporting the main winch for the traction of the cold mass, furthermore, a manual drum and roller for the introduction and removal of the rails inside the vacuum chamber.



5. CONCLUSIONS

The modelling phase, drawing repository of more than 100 engineering drawings, the design calculations and the technical specifications are now completed in preparation for the procurement and manufacture of the cryostat prototype. The record of changes, the technical documentation, and the mounting and assembly procedures also pave the way for the adjustment of existing components and tooling for the manufacture of test cryostats for the 2-m-long magnet models.