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COLLIMATEUR INTEGRATION AND INSTALLATION EXAMPLE OF ONE OBJECT TO BE INSTALLED IN THE LHC

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Abstract

The collimation system is a vital part of the LHC project, protecting the accelerator against unavoidable regular and irregular beam loss. About 80 collimators will be installed in the machine before the first run. Two insertion regions are dedicated to collimation and these regions will be among the most radioactive in the LHC. The space available in the collimation regions is very restricted, it was therefore important to ensure that the 3-D integration of these areas of the LHC tunnel would allow straightforward installation of collimators and also exchange of collimators under the remote handling constraints imposed by high radiation levels. The paper describes the 3-D integration studies and verifications of the collimation regions combining the restricted space available, the dimensions of the different types of collimators and the space needed for transport and handling. The paper explains how installation has been planned and carried out taking into account the handling

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INTRODUCTION

The Large Hadron Collider (LHC) is a two-ring superconducting proton-proton collider made up of eight 3.3 km long arcs, separated by 528 m long straight sections that are also called Insertion Regions (IR). Two Insertion Regions (at point 3 and point 7) are dedicated to the beam cleaning systems capturing off-momentum and halo particles. The 3-D integration studies of these narrow areas were carefully performed taking into account the layout of the general services, the volume of the collimators together with the handling system for installation and removal. The schedule and logistics of installation were followed day per day taking into account priorities, availability of components, co-activities, human resources etc.

INSTALLATION PHASES

The insertion IR3 houses the momentum cleaning systems of both beams, while IR7 houses the betatron cleaning systems of both beams. Particles with a large momentum offset are scattered by the primary jaw of IR3. Particles with a large H, V or combined H-V betatron amplitudes are scattered by the primary collimator jaws in IR7. In both cases the scattered particles are absorbed by secondary collimators. The insertion layout and optics were revised at the end of 2003 in order to reduce the impedance in the insertions and to make room for additional hybrid collimator jaws for the phase II of the LHC collimation system. In order to meet the LHC design goals, a number of sub-systems have been defined which have specific tasks and can be fitted conveniently into different installation phases [1] [2]:

- Phase 1 (2007): Maximum robustness collimators with good cleaning efficiency and an impedance limitation (traded off). This system would be used always for injection and ramp, as well as for early years' physics.
- Phase 2 (2008/9): Phase 1 is complemented with low impedance, high efficiency, but low robustness metallic collimators, located just downstream of each phase 1 secondary collimator. This system would be used only during stable physics and would provide low impedance and excellent efficiency during high current operation.
- Phase 3: Is of no relevance for IR3 and IR7, as this phase refers to the installation of additional collimators for collisions debris in IR1 and IR5.
- Phase 4 (only if required): Additional collimators can be installed for maximum cleaning efficiency, if required.

RADIOACTIVITY ISSUES

The CERN LHC beam cleaning insertions at LHC points 3 and 7 will become two of the most radioactive locations around the entire LHC ring. It is estimated that around 30% of the LHC beam will be absorbed by collimators installed in these regions [3].

Radiation created during the beam cleaning process at LHC points 3 and 7 will cause significant activation of beam line components and other material in their vicinity. Because the particle losses are high, studies have been focused on the assessment of radiation exposure of personnel during maintenance at IR7.

Thus, residual dose rates to be expected during later repair or maintenance interventions must be considered already in the design phase, as intervention time will have to be severely limited.

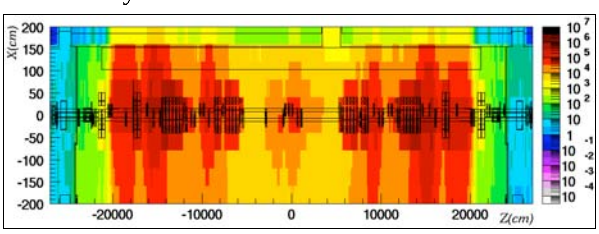

Figure 1 Dose along the betatron cleaning

In order to reduce this radiation exposure of personnel, the studies were carried out closely with the 3-D integration with the aim of putting in place the maximum amont of equipment in first phase of installation and to automate the handling, and survey campaigns in the future.

Handling concept

Special plug – in interfaces have been included in the collimator and collimator support designs to facilitate remote handling. These interfaces allow collimators to be installed and removed from their supports by vertical lifting movements once vacuum connections have been prepared. The cooling water supply and electrical connectors are automatically disconnected [4].

REMOTE HANDLING STUDIES

The decision was taken to use the existing LEP-monorail as support and guidance for the remote handling and transport equipment in order to avoid the associated complexity and costs of an automatic guidance system for the transport of collimators.

The remote collimator exchange equipment conceptual design is in the form of a train suspended from the overhead monorail in the LHC tunnel. This concept is already used for a remote inspection vehicle called TIM (Train Inspection Monorail).

Remote handling of collimators

An initial design concept for the handling equipment based on the use of two crane arms attached to a wagon suspended from the monorail was used to identify the space to be reserved for collimator handling. Integration checks have been carried out to ensure the collimator dimensions and tunnel environment are compatible with remote exchange. Design feasibility studies have been carried out using a 3-D design software package (CATIA) including a more detailed layout design, component designs and calculations.

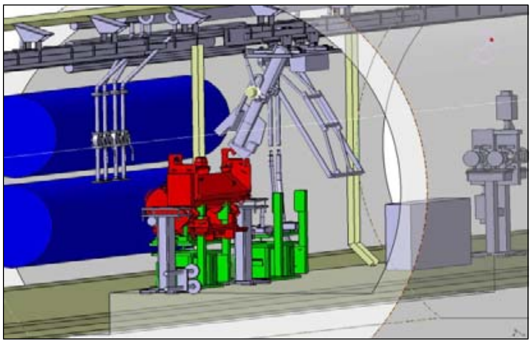

Figure 2: TIM - Collimator survey wagon

Survey

Due to the high collimator residual dose rates, the following alignment constraints should be taken into account:

- Automatic and remote system for survey of alignment stability
- Alignment jacks for all elements, including collimators, should be easily accessible.

In response to these requests, a TIM wagon is under development to be able to remotely measure the collimator alignment. This operation will avoid the need for Survey personnel to spend long periods near collimators to measure the alignment of each one individually. By using this wagon, Survey personnel intervention will be necessary only if collimators need to be realigned.

INTEGRATION STUDIES

Integration studies and measurements have been carried out to ensure that space is available for collimators to be lifted vertically, and space around the collimators has been reserved for handling equipment to allow remote collimator exchange.

Moreover, these studies took into account the tunnel environment composed of general services, machine instruments and the transport zone.

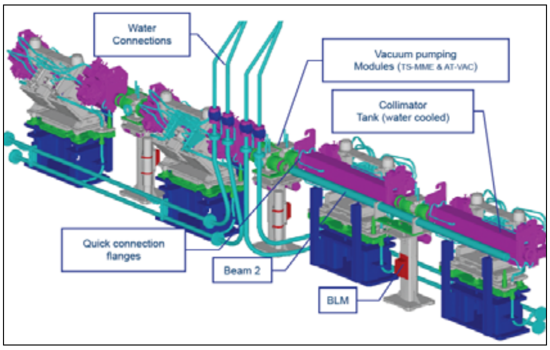

Figure 3: 3D integration in the tunnel

Collimator design

The optimal design for a collimator (protecting a circular beam aperture) would be to use a circular jaw. Since the collimators have to be adjustable in their opening it is much easier (production, alignment, etc.) to use flat jaws. For this reason there are three orientations for the primary betatron collimators (the collimators in the momentum cleaning insertions are mainly horizontal since this is the plane with the highest dispersion) to optimize the coverage (circular approximation).

According to these different orientations, the handling volume has different dimensions. 4 typical volumes have been identified to carry out the integration studies of installation of the collimators into the tunnel.

Tunnel equipment

The LHC integration study takes into account all the major components (cold and warm magnets, electrical feed boxes, dump resistors, racks, electronics crates, transformers, etc.), the services (cable trays, cables, pipes, metallic structures, etc.) as well as the civil engineering works.

The collimation regions house collimators and their equipment; i.e. water pipes for the cooling system, cables for the electronic control, protection covers.

It is important for integration to consider that the other equipment, located near the collimators, have same kind of services (cables, water pipes). Furthermore, the tunnel is sometimes equipped with ventilation ducts, that take up a large part of the available space.

All components must fit into the tunnel, in a particular location, defined during integration studies, in order to allow their installation.

Beam pipes

The nearest machine component of the collimators is the vacuum chamber installed on the adjacent beam. In order to respect the beam optics and the machine layout, the integration must be accurate.

The most difficult zones, where the radial distance between the two beams is smallest, are in points 1, 2, 5, 8. In these areas the two beams converge and so the distance is reduced compared with points 3 and 7

LOGISTICS AND PLANNING

Installation sequences

The installation of collimator system followed the following sequence:

- Survey location marking with respect to the LHC database, floor drilling, installation and alignment of supports,
- Installation of the available collimators,
- Installation of vacuum chamber supports if collimator not available, installation of replacement vacuum chamber, vacuum chamber connection, vacuum sub-sector put under vacuum, de-installation of the replacement vacuum chamber, installation of the collimator,
- Alignment, vacuum connection, bake-out of the vacuum sub-sector once completed, NEG activation, water connection, hardware commissioning of the collimators (the hardware commissioning of the collimators must also follow specific steps which depend on vacuum activities).

In parallel, other teams made the electronic connections in the racks, and on the collimator supports.

Logistics

During the installation of the collimators, the main constraints were:

- ***Component availability:*** At the beginning of the installation, a production schedule was established, taking into account the priorities of the general LHC schedule and the production rate of the different components. This schedule was periodically reviewed with respect to the different delays and hazards encountered either from the production side or form the worksites side.
- ***Human resources:*** The limited resources available for production, installation and commissioning (essentially the same people) obliged the coordination team to carefully follow and optimize the global process, in order to respect the general milestone of the LHC project.
- ***Transport and handling:*** The installation of collimators was carried out using two specially developed trailer –cranes fitted with Palfinger truck – loading cranes. The space needed (120cm wide) to travel along the tunnel and to handle the collimator was taken into account in the planning in order to allow installation in time.

CONCLUSIONS

The 3-D integration, installation and preparation for future replacement of LHC collimators were subject to many constraints. Particular constraints were the limited space available in the LHC tunnel, tight scheduling restrictions, limited resources and high future radiation levels. For this reason the 3-D integration studies, development of special handling and transport equipment, planning and coordination of installation, and the preparations for future remote interventions have relied on close collaboration between several different teams for their success.

The collimation system is one of many systems in the LHC; each system has needed its own specific version of the integration and installation activities described here, tailored to its own particular constraints, and relying on effective collaboration between different sets of people.

ACKNOWLEDGMENTS

The authors would like to warmly thank all the colleagues who have and are participating in the collimation project.

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