INTEGRATION OF THE FORWARD DETECTORS INSIDE THE LHC MACHINE

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Abstract

Several forward detectors have been installed in the LHC long straight sections located on each side of the experimental caverns. Most of these detectors have been designed by the LHC experiments to study the forward physics while some of them are dedicated to the measurement of the LHC luminosity. The integration and the installation of the forward detectors have required an excellent coordination between the experiments and the different CERN groups involved into the design and the installation of the LHC accelerator. In some cases the integration of these detectors has required a modification of the standard beam lines in order to maximise their physics potential. Finally, additional systems have been installed in the LHC tunnel to ensure the operation of the forward detectors in a high radiation environment.

INTRODUCTION

Five LHC projects involving forward detectors have been approved up to date. They correspond to a total number of 44 detectors installed in the Long Straight Sections (LSS) of the LHC machine. The LHCf [1] experiment has installed detectors in LSS1 on both sides of the Interaction Point 1 (IP1). The ATLAS, ALICE and CMS experiments have installed Zero Degree Calorimeters (ZDCs) in the LHC LSS close to the experimental caverns. The TOTEM [2] experiment has installed several roman pots in the LSS5 on both sides of IP5 (see Figure 1).

The integration, installation and operation of the forwards detectors may impact on the LHC machine design. The main issues will be reviewed in the following sections.

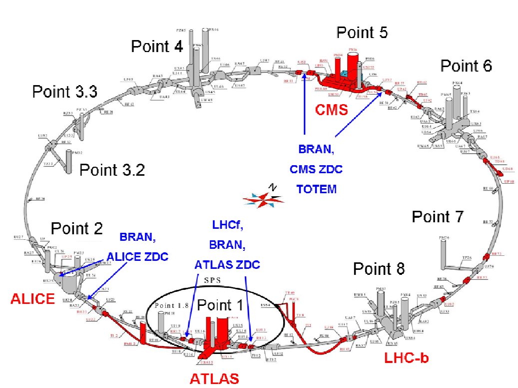

Figure 1: The forward detectors around the LHC.

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FORWARD DETECTORS INTEGRATION ISSUES IN THE LHC

LHCf and ATLAS ZDC in LSS1

The LHCf [1] and ATLAS ZDC [3] detectors have been inserted inside the TAN (Target Absorber Neutral) absorbers located at 140 m from the IP1 on both sides of the interaction region. The TANs are massive machine elements protecting the downstream superconducting magnets (D2) from a quench (see Figure 2). On their top

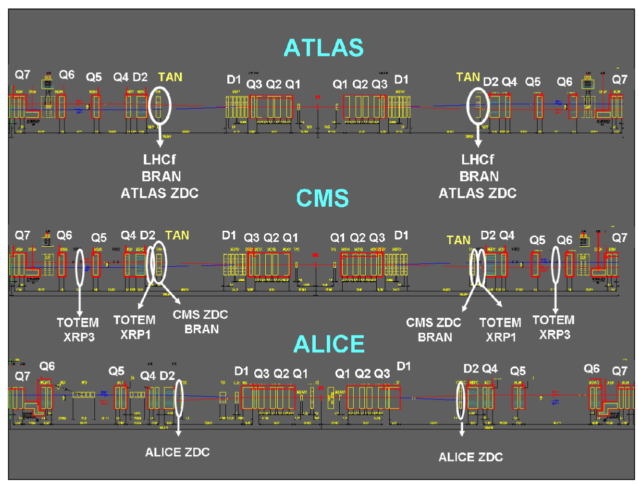

Figure 2: The forward detectors inside the Long Straight Sections.

surface there is a slot, which, in the LHC machine primary configuration, was filled with Cu bars. To allow the forward physics programs, it has been agreed to replace the Cu bars during the low luminosity runs with the LHCf and ATLAS ZDC detectors (see Figure 3). The LHCf detectors will take data during the low luminosity protons runs and they will be removed at a luminosity of 10^{31} cm^{-2} s^{-1}. The ATLAS ZDCs have been designed for the heavy ions physics, but they will take also data during the low luminosity protons runs. The LHCf and/or the ATLAS ZDC detectors provide sufficient shielding of the machine elements during the protons runs with luminosity below 10^{33} cm^{-2} s^{-1}. At higher luminosity the detectors have to be replaced by the Cu bars to avoid the quench of the D2 magnet.

The removal of the detectors will have to be performed during short LHC stops (few days), on request or taking advantage of a foreseen machine stop. In view of the dose levels, the short cool-down time and to ensure safe working conditions to the handling team, the CERN Radio Protection has required remote manipulation of the

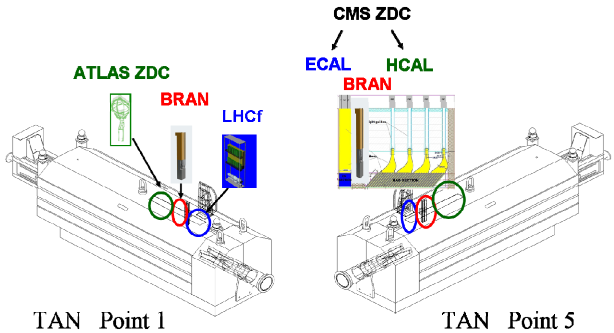

Figure 3: The forward detectors inside the TANs

detectors/Cu bars and their underground storage in the machine tunnel. To fulfil this request, a remote handling system developed by the LHC handling team is under installation above the TANs on the vault of the tunnel (see Figure 4) and two storage concrete bunkers are under construction in the LSS1 (UJs).

Figure 4: The remote handling system installed above the TANs in LSS1.

ALICE ZDC in LSS2

The measurement of the centrality of the heavy ions collisions is essential for the study of strongly interacting matter at extreme energy densities (QCD thermodynamics). It will be done by measuring the energy carried by the non-interacting nucleons (produced at the IP) travelling at zero degree with respect to the beam direction, by means of Zero Degree Calorimeters. One set of two calorimeters have been installed in the LSS2 on both sides of IP2 by the ALICE collaboration [4] (see Figure 2). The spectator protons and neutrons will be separated from the ion beams in the separation dipole D1. Since the D1 magnet will also deflect the spectator protons, separating them from the spectator neutrons (which will travel at zero degree), a set of two calorimeters is needed: the ZN, positioned between the two beam pipes of the recombination chamber, to intercept the spectator neutrons, and the ZP, external to the outgoing beam, to collect the spectator protons (see Figures 5). The two detectors are fixed to a movable platform which will be lowered during injection to protect the detectors from possible beam losses and to minimise the absorbed dose. A number of integration issues had to be solved in order to maximize the physics potential of the detectors and assure their efficient and safe operation. These issues are the modification of the recombination chamber for ZN insertion, the increase of the acceptance for ZP and the reduction of the amount of material in front of both ZN and ZP.

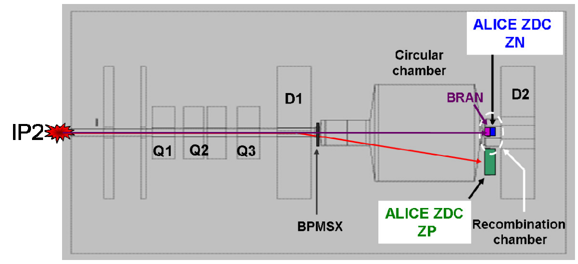

Figure 5: LHC layout around ALICE ZDC

The recombination chamber performs the transition from two beams in a common tube to two beams in separate tubes. Its design minimizes beam impedance subject to beam aperture and space constraints. The presence of the ZN has imposed a special design in order to fit the ZN in between the two beam pipes and leave enough clearance for a safe movement in the vertical plane. In addition, the LHC beam pipes are usually equipped with permanent bake-out jackets in order to restore good vacuum conditions whenever needed. Special ultra-thin bake-out jackets (thickness of 300 μm to be compared to the 4 mm of the standard ones) have been used for the recombination chamber. This allows to leave a clearance of about 3 mm between the ZN and the beam pipes.

The spectator protons entering the D1 magnet suffer a stronger deflection than the Pb ions because of their lower magnetic rigidity. Therefore, the mechanical aperture necessary for the spectator protons along the approximately 50 m long beam line from D1 to ZP is larger than the one needed for the beam (Pb ions). The following items have been modified accordingly:

- Beam Position Monitor, BPMSX: circular aperture increased from 63 mm to 80 mm.
- TCTVB (collimator for the low beta triplet protection), TCDD, TCLIA and TDI (collimators for machine protection at injection): internal aperture, in particular the beam screens, adapted to fulfil the ZP aperture's requirements.
- Circular vacuum chamber (~ 25 m long, in front of the ZN/ZP, see Figure 6): circular aperture increased from 212 mm to 797 mm.

The spectator protons and neutrons exit the vacuum beam pipe at about 2 m and 0.5 m, respectively, from the entrance of ZP and ZN. In order to avoid any degradation of the calorimeters energy resolution, the amount of material between the vacuum beam pipe exiting points of the spectator particles and the calorimeters has to be minimized. Therefore, a 4mm thin window has been

Figure 6: Big circular chamber in front of ALICE ZDC.

machined at the exit of the big circular chamber (see Figure 6) to minimize the amount of material for the spectator protons entering ZP. In addition, the machine luminosity monitor, BRAN, consisting of a CdTe detector and a 15 cm Cu absorber, is placed between the exiting point of the recombination chamber and the ZN. The Cu absorber corresponds to one interaction length and, therefore, it would spoil the energy resolution of the spectator neutrons detected in ZN. Hence, the Cu absorber will be placed on a movable platform which can be lowered down every time the ZN will take data. Finally, the supports of the recombination chamber have been modified to reduce the amount of material.

TOTEM and CMS ZDC in LSS5

The TOTEM collaboration has installed roman pots with detectors on both sides of IP5 in the LSS5 [2]. They are located at 147 m and 220 m from the IP5 (see Figure 2, XRP1 and XRP3) and are directly connected to the LHC machine vacuum pipe. Because of this configuration the eventual removal of a station would require to break the vacuum of the LHC machine along a certain distance. To give more flexibility i.e. to ensure a rapid removal if necessary, the TOTEM collaboration has asked to the LHC machine vacuum group to install additional sector valves close to the roman pots stations. This would decrease the distance on which the vacuum would have to be broken and thus it would decrease the LHC down-time (bake-out period). In the nominal collimation scheme (see Figure 7), the TCL collimator has been installed between the Q4 and Q5 magnets to protect Q5 from the debris coming from the IP5. The simulations show that the TCL should stay open until a luminosity of about 3-5 10^{33} cm^{-2} s^{-1}. However, the TCL will be closed as required by the machine operation. This closure will reduce the acceptance of the roman pots at 220m. When the LHC will reach a luminosity of about 10^{33} cm^{-2} s^{-1}, the TOTEM XRP1 stations will have to be removed and replaced by the TCLP collimators to protect the RR alcoves and the machine Dispersion Section located downstream from the IP5 debris. The XRP1 stations are required to fulfil the TOTEM physics program at high beta (β^*=1540 m) implying that the TOTEM physics program foreseen with high beta has to be completed before the TCLP installation becomes necessary.

The CMS ZDC detectors [5] have been inserted inside

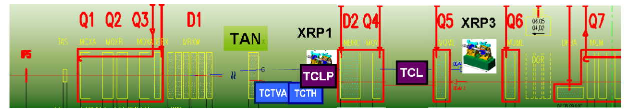

Figure 7: Nominal collimation scheme in IR5.

the TAN absorbers located at 140 m from the IP5 on both sides of the interaction region (see Figures 2 and 3). The detectors will take data during the protons runs at luminosity below 10^{33} cm^{-2} s^{-1} (radiation hardness limit and D2 protection issue) and during the heavy ions runs. For the same reasons as for the ATLAS ZDC (see above) the CERN Radio Protection team has required remote manipulation of the CMS ZDCs/Cu bars and their underground storage in the machine tunnel. A remote handling system is under study by the CMS collaboration and should be installed during the long shutdown 2011 - 2012. It will be mounted on the TAN top surface. Its installation will only mean the longitudinal displacement (few centimetres) of one of the LHC survey reference fiducial located on the TAN top surface. The storage bunkers have been installed in the LSS5 (UJs).

CONCLUSION

The integration and installation of forward detectors in the LHC LSSs has required several modifications of the machine elements. Five projects involving forward detectors are now in place and will take data during the first LHC runs in 2009.

There are new proposals for projects with forward detectors to be installed far away from the IP regions. Their feasibility is under study.

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