EXPERIMENTAL EQUIPMENT INTERFERING WITH BEAM OPERATION

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Abstract

The experimental magnets and movable detectors will have an impact on beam operation. It is therefore very important that their operation follows procedures established in agreement with the LHC machine. It should be underlined that, at the moment, procedures are established according to our best knowledge of what the LHC operation will look like. However, the real challenge in the operation of these devices will become clear only when the machine will become operational. Therefore, it would be advisable to keep the procedures and their implementation as flexible as possible in order to be ready for possible modifications which may be required once the LHC will be operational.

EXPERIMENTAL MAGNETS

The LHC experiments are all equipped with magnets:

- ATLAS is equipped with a central solenoid and barrel and endcap toroids
- CMS is equipped with a solenoid
- ALICE is equipped with a solenoid (ex L3) and a dipole
- LHCb is equipped with a dipole

The dipoles will distort the beam orbit and their effect has to be compensated locally with dedicated compensation magnets [1]. Solenoids create couplings and orbit distortions that in some cases need to be compensated [1]. It is therefore clear that their operation is in general related to beam operation. The dipoles need clearly to be operated together with the associated compensators and ramped with energy and this will be done by the machine. The ALICE solenoid's polarity is linked to the one of the dipole. Hence, it is more practical if the machine operates both magnets. For what concerns ATLAS and CMS, the magnets will be operated by the respective experimental control rooms (at least during the first years of operation). In fact, their operation has an important effect on the detectors which need to be studied in detail during the commissioning period and the first period of data taking. It should be noted that the hardware is such that the magnets can be controlled from any control room, CCC included.

It is clear that the status of the magnets will have to be monitored in the CCC. Hence, the experiments have already foreseen to send the related information via the LHC Data Interchange Protocol (DIP). Beam interlocks related to the status of the magnet may be implemented if required by the LHC operation. Finally, a procedure for their operation needs to be agreed between the experiments and the machine before the LHC start-up.

MOVABLE DETECTORS

Movable detectors will be installed in all 4 IRs. ATLAS and TOTEM will install Roman Pots in the LSS at IR1 and IR5 respectively while LHCb will install the Vertex Locator in the LHCb experimental cavern. All these detectors will move in the primary vacuum of the machine and will have to be positioned at a few millimetres from the beam axis. Wrong operation of these devices or of the beam itself may result in an accident with serious consequences for both the detector and the machine. The ALICE Zero Degree Calorimeter (ZDC) is operated outside the primary vacuum of the machine. However, given the small clearance between the moving ZDC and the vacuum beam pipe, its operation deserves particular attention.

Alice ZDC

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) flying at zero degree with respect to the beam direction, by means of Zero Degree Calorimeters (ZDC). One set of two calorimeters will be installed in the LSS2 on both sides of IP2. The spectator protons and neutrons will be separated from the ion beams via the separator magnet D1. Since the D1 magnet will also deflect the spectator protons, separating them from the spectator neutrons (which will fly at zero degree), a set of two calorimeters is needed: the ZN, positioned between the two beam pipes, to intercept the spectator neutrons, and the ZP, external to the outgoing beam, to collect the spectator protons. In addition, the ZN calorimeters will be used for the monitoring and precise measurement of the heavy ion luminosity. The ZP may also be used during the pp runs to study diffractive events. The ZDCs are placed on a remotely controlled platform which moves in the vertical plane and that will bring the ZDCs from their garage position, i.e. 20 cm below the beam level, to the data taking position at the beam level. The garage position will protect the ZDCs from possible injection errors and it will minimize the absorbed dose when data taking is not required. Once the ZDCs are positioned at the theoretical beam level, small fine adjustments may be needed to centre the detectors on the real beam level. An injection inhibit will forbid beam injection if the ZDCs are not in the garage position.

Even if the ZDCs do not interact with the LHC primary vacuum, special attention must be paid to their operation since the clearance between the detectors and the beam vacuum pipe is only of about 3 mm. This clearance is not of a concern with a ZDC well positioned and aligned. However, accidents and mistakes during the work carried out during access time, may miss-align the ZDCs and, if not detected in time, lead to serious consequences. Therefore, anti-collision switches and a top cover have been recently introduced in the design of the ZDC platform to detect possible miss-alignment and minimize the possibility of accidents due to mistakes (Figure 1). The top cover is also required for personal protection as for all machines remotely controlled.

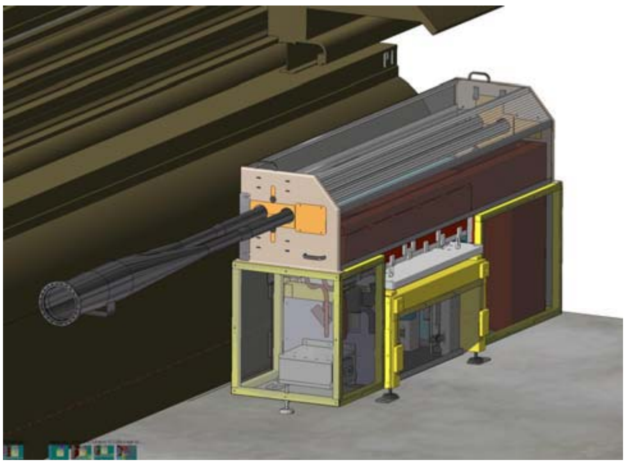

Figure 1: ZDC platform with the top cover

The machine luminosity monitor [2], placed in front of the ZN, may degrade the performance of the detector. Studies carried out by the ALICE Collaboration show that, if the absorber required by the luminosity monitor is of the order of 10-20% of an interaction length, the energy measurement is not affected. However, the effect on the measurement of the impact position of the particles needs further studies. Nevertheless, if the presence of the luminosity monitor will be shown to be incompatible with the operation of the ZN, backup solutions are available. In fact, in this case, the absorber can be put on a movable support and the ZN can be used as the machine luminosity monitor during the heavy ions runs [3].

The ALICE Collaboration will be responsible for the operation of the ZDCs. However, the Collaboration underlines that the ZDC is placed in a zone which is completely under the responsibility of the machine. Therefore, it will be impossible for ALICE to monitor the activities carried out in the zone and be aware of the possible consequences for the ZDC operation.

LHCb VELO

The VErtex LOcator has to provide precise measurements of track coordinates close to the interaction region. For this, the VELO features a series of silicon stations placed along the beam direction. They are placed at a radial distance from the beam which is smaller than the aperture required by the LHC during injection and must therefore be retractable. Figure 2 is a schematic of the VELO design. A description of the VELO detector can be found in [4].

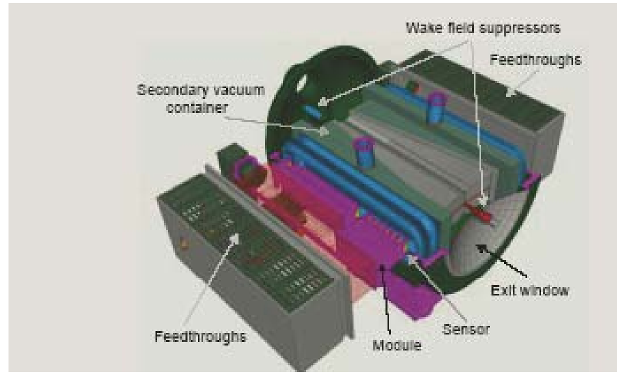

Figure 2: A schematic of the VELO design

VELO will be operated from the LHCb Collaboration. It is able to move along the horizontal plane and also in the vertical plane to adjust it symmetrically with respect to the real beam axis. Following a wrong operation, VELO could touch the beam with serious consequences for both the detector and the machine. The VELO operation will make use of an on-line monitoring which is able to reconstruct, in a fraction of a second, the collision vertices and, therefore the luminous region, with a precision of ~ 10 μm in the transverse plane. In general, VELO will not move in the absence of collisions. The VELO will be protected by an interlock system (as described in [5]) based on the knowledge of its position and on the signal from the radiation monitors located close to it. The radiation monitors are supposed to detect the signal from dangerous situations like beam scraping or touching the VELO vacuum shield and dump the beam before either VELO or the machine gets damaged. However, the effectiveness in discriminating the signal over the background from pp interactions has still to be demonstrated. It should be noted that the details about a safe operation of the VELO detector will become clear once the machine will be operating. VELO is able to go back to its garage position in about 5 minutes if beam operation requires it. However, it should be taken into account that the retraction and the repositioning of the VELO detector will cause a loss of physics data and that, therefore, it will be performed only if required for safety reasons.

Roman Pots

The Roman Pots will be installed in the LHC tunnel around IP1 (ATLAS) and IP5 (TOTEM). The TOTEM Roman Pot station is composed of two units with each unit consisting of two pots that move vertically and one that moves horizontally (see Figure 3). The ATLAS Roman Pot is similar but it does not have the horizontal pots.

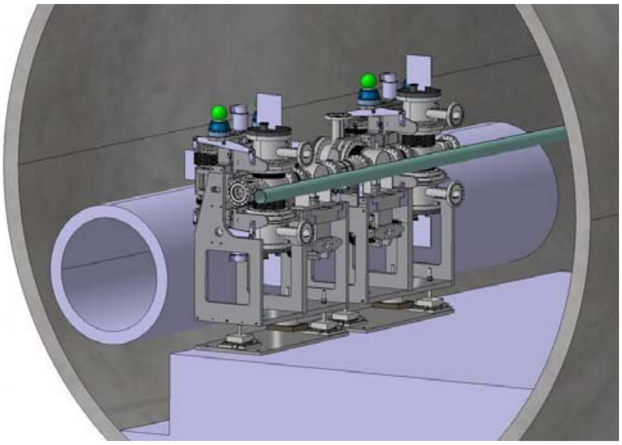

Figure 3: TOTEM Roman Pot Station

The Roman Pot operation is very similar to the VELO operation. The main difference is that the operational distance from the beam is smaller (~ 2 mm) and comparable to that of the tertiary collimators. In addition, the Roman Pots are not equipped with an on-line monitoring able to measure the beam position with very high precision. However, as in the VELO case, due to wrong operation, the Roman Pot is able to touch the beam with serious consequences for both the machine and the detector. The Roman Pots will be protected by an interlock system (as described in [5]) based on the knowledge of their position and on the signal from the Beam Loss Monitors located close to them. The movement will be guided by the response of the BLMs and of the Beam Position Monitor integrated in the Roman Pot design. The final position will be determined looking at the signals from the detectors. If beam conditions, like beam halo, are not good enough the Roman Pots may not be able to reach their nominal position to avoid too many faulty triggers which may compromise the quality of the data taking. LVDT sensors and resolvers will also be used as redundant information on the position of the pots. TOTEM proposes to interlock the position of the Roman Pots once the data taking is started since accidental movement of the pots may compromise the data quality. This proposal is actually under the evaluation of the Machine Protection Working Group. In fact, this proposal is not entirely compatible with machine safety, since, under very particular circumstances, it may be required to retract the pots as soon as possible. Clearly a compromise is needed. The experiments have finally agreed to operate the Roman Pots from the CCC given the tight relation between machine operation and Roman Pot operation. Should in future Roman Pots become a routine operation, a revised procedure may be required if the Roman Pots positioning will result in a non negligible overload for the operators in the CCC. Since the Collimator Control System will have to ensure that the Roman Pots are always in the shadow of the collimators for safety reasons, the Roman Pots Control System will be integrated into the Collimator one. A preliminary agreement has been reached in the COCOST meeting held in October 2005. The experiments will be responsible for writing the functional specifications for their system and of the implementation of the software of the low level systems of the Roman Pots Control.

CONCLUSIONS

Responsibilities for the control of the experimental equipment with an impact on beam operation has been clarified and agreed between the machine and the experiments. Detailed procedures on their operation need to be sorted out before the LHC start-up with the awareness that only experience in LHC operation will certify the correctness of these procedures. A non negligible amount of work needs to be done on the Control System of the Roman Pots to be operational before the LHC start-up.

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