Status of the \textit{LHCb} detector commissioning and first running scenarios

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Abstract. The \textit{LHCb} experiment is dedicated to the study of CP-violation and rare decays through the production of B mesons. The installation and commissioning of the detector is ongoing and the detector should be ready for the first proton beams delivered by the LHC machine. The strategy to commission the detector and the first running scenarios are reviewed here.

1. Introduction

The LHC should provide the first proton beams in 2008. \textit{LHCb} is one of the four detectors located at the proton-proton interaction points of the accelerator. It is devoted to the study of CP violation and of rare decays through the production of B mesons. \textit{LHCb} will benefit from a large statistics due to the B meson cross-section at 14 TeV, from a large $P_t$ of the B mesons decay products and from the presence of secondary vertices.

\textit{LHCb} is a one arm spectrometer (see figure 1). The proton-proton interaction point is displaced with respect to the center of the hall where the detector is located \cite{1}. The first equipment seen by the particles produced in the collision is the vertex locator (VELO). Then, the particles cross the volume of the first Cherenkov imaging system (RICH1). Apart from the VELO, the \textit{LHCb} tracking system consists of the trigger tracker (TT) in between the RICH1 and the magnet. After the magnet, three tracking stations (T) comprise a silicon-strip based inner region and a straw tube outer part. The calorimeter system is located after the second RICH (RICH2) and is made of 4 parts, the scintillating pad detector (SPD), the preshower (PRS), the electromagnetic (ECAL) and hadronic (HCAL) calorimeters based on scintillating media coupled to photomultipliers. Finally, the muons system is the last active equipment seen by the particles.

2. Commissioning Strategy

The commissioning of \textit{LHCb} has started in 2007. The first steps consisted in commissioning independently each sub-detector. The safety issues were checked and hardware operations, controls and monitoring have been tested. Time delays have been set to reasonable values leading to the coherency of the data produced by each sub-detector. The cabling for the data acquisition and the trigger was tested. A specific movable rack was designed in order to provide to the sub-detector groups the Time and Fast Control (TFC) signals (clock, trigger and fast
commands), the slow controls and a mini-farm of computers to perform the readout. Calibration pulses have been used also to test the response of the hardware. A full test was performed in spring 2007 with the electromagnetic and hadronic calorimeters and the first level trigger, called level 0 (L0). The standard Time and Fast Control of the pit was partitioned in order to control the calorimeter system and provided a calibration command to the HCAL. This caused the firing of LED pulses in a specific region of the HCAL whose cell signals were recorded and treated in the front-end boards. The pulses were such that they exceeded the trigger thresholds. The trigger signals were propagated from the trigger validation boards located in the front-end crates to the selection and the L0 decision unit boards located in the barracks through optical fibres. The trigger yes-decision was sent to the TFC system which validated the L0-trigger and caused a download from the front-end buffers through the DAQ path of the data corresponding to the calibration pulse. The exercise was pushed to the storage of the events on the computers of the farm already installed in the pit and to the display of the events in the control room. The HCAL trigger was tested and validated during that test. This is a key element to commission the rest of the detector and for the first running periods.

Some calculations and measurements performed in the cavern indicate that the cosmic rate is high enough to synchronise the 4 calorimeter systems (ECAL, HCAL, SPD and PRS) and the calorimetry with respect to the tracking chambers and the muons. Cosmics are planned to be used before the end of 2007.

3. First running scenarios

The LHC will most probably start its operations with a downgraded luminosity and reduced number of bunches. The energy may also be lower than the planned 14 TeV. Nevertheless, these conditions allow to perform most of the commissioning tasks required to check the detector and tune the settings of LHCb.

3.1. Time alignment

To ensure the events readout by every sub-detector are synchronized properly, particles are required to traverse the full apparatus. Time alignment will be the first task, whatever the energy and the luminosity provided by the machine. A specific trigger and readout mode has been designed for that purpose. The trigger will be accepting only HCAL decisions and the DAQ will be set such that it will acquire five successive clock beats (corresponding to five potential bunch crossings). The two first will be just before the HCAL yes-decision, the central one will correspond to the actual HCAL event and finally the two following ones. At low luminosity, the
central sample should be the only one to have any activity in the detector. This will be true for the HCAL by construction. The delays and settings of the other sub-detectors will be tuned for them to be synchronized with the HCAL and have activity in the same central clock beat out of the five consecutive.

3.2. Space alignment
Space alignment has an impact on the physics analysis and on the high level trigger that relies on the tracking. During installation, the position of the tracking system is constantly surveyed and a precision of a few hundreds $\mu m$ is achieved. The first particles should allow to evaluate the internal alignment parameters of every detection plane. Segments of tracks may be reconstructed in the VELO and the T-Stations. Minimisation techniques are used to extract the alignment corresponding parameters [2].

During injection, the VELO is retracted 3 cm away from the beam. It is brought progressively to its nominal position, i.e. 8.16 mm from the beam line after physics conditions are established by the machine. The expected space alignment precision of the VELO is 2$\mu m$. This has been validated during several Alignment Challenge and Detector Commissioning test-beams performed in 2007. The VELO, TT and T-Stations may be aligned altogether by connecting track segments produced by charged particles. To reduce the complexity, the alignment will be first performed with the magnet off, which will be most certainly the case if the beam energy is reduced at the LHC start up.

Finally, the other sub-detectors will be aligned with respect to the tracking system. The ECAL, HCAL and muon system are supposed to be already positioned with a precision better than 1 mm. Electron and muon samples will be used to improve the knowledge on their alignment.

3.3. Momentum and Energy calibration
Momentum resolution depends on the tracking system alignment but also on the magnetic field uncertainties. The $B$ field is supposed to be flipped regularly to understand detector asymmetries. Its components have been carefully measured with a precision better than 0.03%. The total effect is supposed to contribute less than 10% to the momentum resolution uncertainty. The momentum scale can be corrected by measuring the mass peak of reconstructed $K^0_S$, $J/\psi$, $\Upsilon$, $Z^0$, etc...

Several techniques are under study to calibrate the ECAL and lead to different precisions. Before installation the modules have been calibrated with cosmic rays up to 10%. Energy flow methods should permit to reduce the uncertainty down to 1%. More sophisticated iterative methods based on the reconstruction of the $\pi^0$ mass may improve the precision up to less than 1%.

4. Conclusion
The LHCb experiment is being commissioned actively. The first running scenarios have been prepared to make the most of the first beams and start-up conditions of the LHC. The purpose is to get to stable running operations and extract physics measurements as soon as possible.

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References
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