

LHCb Commissioning Strategy

LHCb Commissioning group

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Abstract

The commissioning strategy of LHCb is summarized in this document, starting from sub-detector commissioning, followed by the commissioning without beam and the use of beam for commissioning, up to the Pilot Run end of 2007.

1. Overview

The commissioning of the LHCb detector has already started, as some part of the detector is already installed in the cavern (magnet, RICH2, Ecal and Hcal) and more is scheduled to come in the next months.

The commissioning strategy can be divided into three steps:

1. Commissioning of each individual detector by the relevant experts.
2. Commissioning of LHCb as a whole without beam, exercising the control system and validating the beam-less calibrations procedures.
3. Commissioning with beam, to insure a proper readout and trigger.

This is a long project, spanning over more than a year, and a detailed description of each step to be performed would be too ambitious. The purpose of this document is to identify the main activities, and to list their dependencies (what has to be done before), how they will be performed (needed tools) and estimate their complexity and duration. This is clearly a first estimate, to be revisited regularly.

2. What should be done by the Sub-Detector groups

Clearly, those who built the detector should make sure that it works once installed at the pit! This means that the initial tests are under the responsibility of the project. This includes the software for controlling the detector. It is clear also that the detector builders are best to guess the initial settings of time alignment, high voltage and other operating parameters. Most of the work will be done in 'local' mode, working close to the detector with the "portable rack".

2.1. Controls

The project should provide the PVSS application to control their system. This should clearly be done in close contact with the ECS part of the Online project, using as much as possible standard components. Crate control, HV control should be taken as provided. TELL1 control has to be adapted to control (and monitor) the detector specific part of the code. Front-end board configuration has to be provided, using also centrally provided template. Any other system requiring PVSS control should also be provided in close contact with Clara and co, so that integration in the overall LHCb ECS is straight forward.

2.2. Cabling

Cabling is the responsibility of the detector projects. All internal cabling has to be made, and checked. The project must guarantee that the device controlled is the correct one, being a crate, a board, a test system or any other element. The same apply for all internal cabling, which is mainly for the detectors contributing to the Level-0, where data is exchanged between modules, while other detectors have a simpler and more linear sensor-to-readout connection. As the number of connections is large, tools to check these connections have to be built, and it should be done in a standard way so that they can be re-used for regular checks, e.g. after any access for hardware intervention. Connections starting from the TELL1 towards the DAQ and control system is the responsibility of the online group.

3. Global commissioning without beam, Spring 2007

This period will start around February 2007, and should aim at making LHCb a **single experiment**, instead of a collection of individual detectors. The work will be a close collaboration of SD experts, Online project team and Commissioning group, in order to get the detector ready for the first circulating beam, and then the first collisions. The transition from single detector work to complete LHCb control will be in several small steps, and there is no need to have all detectors internally commissioned, nor all detectors complete, to start the Global commissioning. Working with only half ECAL, or only one half OT station, will allow debugging a lot. However, we must also exercise early enough the full load on the system, i.e. see that a cold start of the complete LHCb readout takes an acceptable amount of time.

3.1. Use of cosmics?

This is a recurrent question: can we usefully use cosmics to commission the detector? This seems not obvious, due to the geometry of the detector, and to the random time of arrival compared to our LHC clock. We have limited triggering capacity at Level-0: The Pile-Up System is

too small. The L0-Muon will select only muons pointing to the interaction point, and there are very few cosmics almost horizontal. L0-Calo could detect activity in HCAL, where almost vertical cosmics can be seen. But this would be limited only to the Calorimeter systems, as again these tracks would not reach the T stations, and not be of any use for the RICH2 or the muon system. As a consequence, **our commissioning strategy will not rely on using cosmics**, but if LHCb is commissioned and running while beam is not yet available, we could try to get some cosmics just to keep us busy.

3.2. System integration

One of the most important tasks will be to integrate the complete system, in terms of control, so that a run can be started and stopped with all detectors and that concurrent activities can take place in different partitions. This will be mainly a lot of cold starts, changes of partition, change of the farm configuration and so on.

Error handling should also be commissioned at this time: Error reporting, actions upon error, procedure to restart. Slow control problems should have been already investigated during SD commissioning, but should be validated in the global context. Partial power cut should not create a flood of message, and the operator should see only the important information. But the most delicate aspect will be readout errors. Handling missing source, de-synchronisation, restarting after missing information should be tested.

3.3. Initial time alignment

The only real way to do the time alignment will be with beam, as we want to make sure we collect together measurements of the same particles from the same crossing. Without beam, i.e. without real particles crossing the detectors, there is almost no possibilities to check that we readout the same event. Setting the initial values of the various delays should be done by computation on paper. It can be tested by using test pulses in most detectors, taking into account the cabling of the test system too. This will not give an absolute timing nor a correlation between detectors, but will insure that only the global timing of the detector has to be found with beam. Due to possible differences between the test pulse properties and real particle signals, this will equalize the timing of the various channels only to a certain accuracy, probably a few ns, and the final fine adjustment will be done with real particles from interactions.

One path that can be checked is the HCAL – Level-0 internal timing: With the LED-generated light pulses, the HCAL Level-0 will trigger, and we should readout this pulse in the DAQ. This is not exactly the same as the usual LED calibration sequence, as in this case the L0 Yes is sent by the Readout Supervisor at an appropriate time. Commissioning this HCAL L0 trigger will insure that we can trigger and readout the first beam gas events that will deposit energy in HCAL.

However, the procedure to perform time alignment should be validated: Reading consecutive crossings, and processing them together, is a non standard activity. This will require development in processing a complete Multi Event Packet as a whole, in accessing several events simultaneously in Gaudi, in comparing readings of the same cell in consecutive BX and in deciding what the best timing is. Part of it is already developed, Boole can process a single Monte-Carlo event and produce a multi-crossing event, as it will appear in the EFF or in the Monitoring farm. User code to analyse these events could be developed and tested from now on.

3.4. Calibration events

These events are used mainly/only by the calorimeter systems, to measure the gain of the 13500 PMT channels. As a first step, probably done by the calorimeter alone, one should make sure that the ADC values correspond to the light pulse, which implies a first part of the time alignment has already be done by the calorimeter. The handling of these events, in the middle of a normal data taking, should be validated, and their routing to dedicated nodes (Calibration Farm) tested.

Another issue is the running of SD specific electronics tests before data taking. Part of these tests will eventually be run before / after each fill. The procedure to do so can be commissioned before any beam.

4. Commissioning with beam, end of 2007

The conditions in which the machine will start are now better known. The 2007 run, sometimes called Engineering Run, will be at injection energy (450 GeV per beam) with wider beam size (4 times wider than nominal), limited current per bunches ($2 \cdot 10^{10}$ instead of 10^{11} nominal) and a low number of bunches: Initially, a single bunch will be used, giving collisions only in Atlas and CMS. Then it is foreseen to have 43 bunches per beam, with 4 displaced bunches in one beam to give collisions in LHCb. In this configuration, the luminosity will be lower than nominal by a factor 0.25^2 (spot size) $\times 0.2$ (bunch intensity) $\times 4/2980$ (colliding bunches), which means $1.6 \cdot 10^{-5}$ not counting the energy dependence, such that we can expect a luminosity lower than $3 \cdot 10^{27} \text{ cm}^{-2} \text{ s}^{-1}$, which can also be expressed as ≤ 100 Hz of minimum bias events. Our magnet will be initially OFF, to simplify the injection. The Velo will be in garage position, 3 cm from beam axis, but can be moved to the nominal position when "Stable Beams" have been declared.

There are clearly many things that can already be done with a single beam at injection energy, provided it is in the proper direction. We may expect a one or two weeks with some beam in that configuration, but not that much. This could provide already some particles crossing the detector with a reasonable timing, as there will be beam-gas interactions. If the interaction is a bit upstream from the nominal IP, we could even have at the same time Velo hits and hits in all other detectors, and thus start the time alignment, even if the rate is low and the presence of beam intermittent.

4.1. Timing alignment

The procedure is similar to the one previously mentioned: Select events with activity in HCAL using Level-0 trigger, and record 5 consecutive crossings, two before and two after. One can think of selecting no activity in these 4 neighbouring crossings, but this is NOT necessary at the low initial crossing rate and luminosity. These 5 events should be processed as a single block of information, with a dedicated application, including MEP decoding. This application should pass control to sub-detector dependent algorithm that will get the 5 samplings of every channel and measure the time of the deposit compared to the readout time. This processing is sub-detector specific, as the shape of the signals versus time is different: Silicon detectors (Velo, ST) have a non negligible spill-over, the Calorimeter have almost no spill-over, OT measures time spectra spanning over 2 or 3 crossings, and adjust on the leading edge of the spectrum. The purpose of this alignment is to find the best settings of every programmable delay in the system, which means that channel should be grouped according to the grouping of the programmable delays. One should also clarify in advance what should be optimised, either minimizing the amount of spill-over or optimising the amount of signal. The first choice seems easier, and seems also to

optimise the gain for most detectors. But this has to be defined and implemented by the sub-detectors.

It should be noted that the time alignment of the Muon detector will be done somewhat differently. A time alignment with a procedure similar to the one described above is foreseen without requiring the acquisition of consecutive crossings (it can be done through the ECS system using the foreseen histogram facilities in the ODE). But such a procedure in the case of muon detector does not provide the best time alignment because the large majority of the hits are not muon hits and have a different temporal behaviour depending on station and region. A fine time tuning will be necessary to get the best trigger efficiency and will be performed selecting muon hits and using the time of each channel that is recorded with each event (4 bit TDC scanning over 25 ns). Muon tracks are almost straight line (no matter if magnetic field is on or off), and very fast pattern recognition can select muon hits at a reasonably high rate, permitting the usage of the time associated almost online.

4.2. Moving the Velo to its normal position

Due to the hardware interlock implemented, the Velo can not leave its garage position (3 cm away from the beam) until LHC has set its mode to "Stable Beam". It will take some time in the LHC startup until this state is reached. In a sort of chicken-and-egg problem, the alignment should be done with the Velo at its nominal position, closed around the luminous region. But to get the luminous region, one need to reconstruct the tracks, which require some acceptable alignment. In fact, the quality of the alignment needed for the pattern is easily obtained by construction, and should then not be a problem. Moving the Velo to its nominal position will clearly be a major event in the commissioning, and should not be delayed by unavailability of the software to measure the luminous region while the Velo is moved gradually IN.

Events can be simply triggered by the HCAL trigger, with enough downscaling to not saturate the readout. The code in the event filter farm will essentially select events with activity in the Velo, and then run the open velo reconstruction. This may require some knowledge of the current settings of the Velo motion system, which will then have to be fed back to the EFF nodes. It should be noted that this sequence of operation, moving the Velo to around the luminous region, will take place at every fill, and should become rapidly a very automated and routine operation. In normal mode, the position of the beam will be measured with the Velo fully opened, and the Velo will then be asked to move to its final position in one step. Of course, this operation will be divided in smaller steps during commissioning, to avoid taking any risk: One could move from 3 to 1 cm, check again the position of the beam, and go to a not-completely-closed position if needed.

4.3. Alignment

Once we know that we readout the data from the same crossing (Time Alignment), aligning the detector in space is the next important step, which is needed to get the HLT trigger working. As indicated earlier, the first collisions will be with magnet OFF, and will be used to collect straight lines. The Velo internal alignment should come from the test beam and initial metrology, and should give a very good starting point for aligning the other detectors. This alignment is essentially an analysis task, as there is no configuration of the detector to change after alignment. Collecting enough data will be the main requirement to the commissioning activity. If corrective actions are needed on the detector position, they will have to be performed during a long enough access, this means most probably after the Pilot Run. This should not be the case as the detectors will have been surveyed.

A misalignment of the MUON DETECTOR affects the L0 performance. Software corrections could be eventually envisaged for the HLT but a reasonable hardware alignment (~1mm in the

inner region) should have been attained during installation. The alignment can be efficiently checked collecting high momentum muons with magnet on and OT operating. In the absence of magnetic field, reconstruction of tracks pointing to IP is possibly sufficient for a reasonable alignment (to be studied in detail). The correction of the chamber alignment is a heavy procedure.

4.4. First data with magnetic field

As soon as possible in the commissioning of the LHC, and once we have done the basic time alignment, we should ask for collisions with our magnet ON. This is mandatory to start working on the software trigger, to validate the simulations and tune the reconstruction. This is also needed to commission the Level-0 muon trigger. As the luminosity will be very low a simple Level-0, asking for a minimal energy deposited in HCAL, will select events useful for understanding the trigger and for working on reconstruction. Unfortunately, the Velo can't be closed with full field at 450 GeV. However, it can be partially closed (probably ± 1 cm from beam, maybe less) and should be able to give tracks at the vertex with reasonably good efficiency.

5. Summary

Commissioning will start with a time aligned HCAL trigger setup with LED. It will trigger on the first beam gas events, allowing to time align other detectors before the first collisions. No filed data will be taken first, as this is the most probable LHC startup scenario, and as these data will be very useful for alignment. As soon as we have enough time aligned data with no field, we should start data taking at nominal filed, with the Velo partially opened, to start understanding reconstruction and prepare the work for the trigger, event if it is not needed for the Pilot run.