PROCEEDINGS OF SCIENCE

LHCb Commissioning

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This presentation reviews the status of the commissioning of the LHCb experiment at the LHC. After describing the goal of the commissioning, the various steps taken so far are described: Use of test pulses, triggering on cosmics, analysing TED events and the few beam induced events that have been recorded in September 2008.

2008 Physics at LHC
Split, Croatia
September 29 – 4 October 2008

[1] Speaker

PoS(2008LHC)072

1. Introduction

Before discussing the LHCb commissioning, it is useful to discuss what is commissioning. First, this means bringing all components of the experiment, sub-detectors and services, into their operational state. This means also implementing and validating the various tools and procedures needed to run the detector as a whole. And it means also organizing the activities to reach the ready state in time for the startup of the accelerator. But this is only part of the goal, the technical part. The most important result of the commissioning activity is to build a **team spirit**. By this I mean to transform the collection of independent teams that have built the various sub-components of LHCb, and were used to work without too many constraints, into a single team working for the experiment as a whole, and thus accepting constraint of other groups and systems and helping each other. This evolution takes time, but is the key to get an efficiently working experiment.

The commissioning activity of LHCb started in 2006, with regular meetings mainly devoted to discussion of specification documents, and of scenarios for commissioning and operations. The main purpose was to clarify what had to be implemented, and by whom. This was also to clarify the image we had on how the experiment should operate: Central control with a limited shift crew, no sub-detector shifts after the startup, piquets for regular checks and first help in case of problems. Starting in early 2008, monthly commissioning weeks were scheduled, during which as many systems as possible were controlled and readout together, to identify problems and make people working together, learning to know the way the other act and speak. This is important to avoid frictions and misunderstandings later. From July 2008 on, regular shifts were scheduled, first only during working hours, then 24 hours a day 7 days a week from August 18th until the LHC broke.

2. Technical challenges

2.1 A central control system

The choice of LHCb is to run the experiment form a central console, in a coherent way so that the configuration of the whole system, from front-end electronics to event filter farm, can be done in a few click in a reasonable amount of time: 10 minutes for a cold start, one minute if the front-end is already configured. The whole system should also be centrally monitored, with a central alarm and error screen, a coherent monitoring system allowing all plots to be accessible from a central place. The detectors should be run with a limited crew; two persons should be enough, with a first line support of ‘piquet’ for each system.

2.2 Readout at 1 MHz

The hardware trigger is designed to run at 1 MHz, and the full information of the accepted events is send to the event filter farm at this rate. In 2008, the network and farm are not completely installed, and the rate limit is at 100 kHz: Buying later gives more for the same money, and there was no need to get that high a rate in the LHC startup year.

2.3 Data storage at 2 kHz

The accepted event rate is defined as being 2 kHz written to storage. This system is fully implemented and was commissioned at a rate even somewhat larger.

2.4 Time alignment to a few nanoseconds

One of the challenges of the LHC is to separate events 25 ns apart. We have decided in LHCb to be able to read consecutive beam crossings from a single trigger decision, this means up to 7 crossings before and after the one having produced the decision. This allows finding where is the signal on the initial events, and then to optimize the time alignment by minimizing the leakage of the signal in the previous and next crossings.

3. Commissioning with cosmic rays

LHCb is not well suited to look at cosmics as can be seen on Figure 1

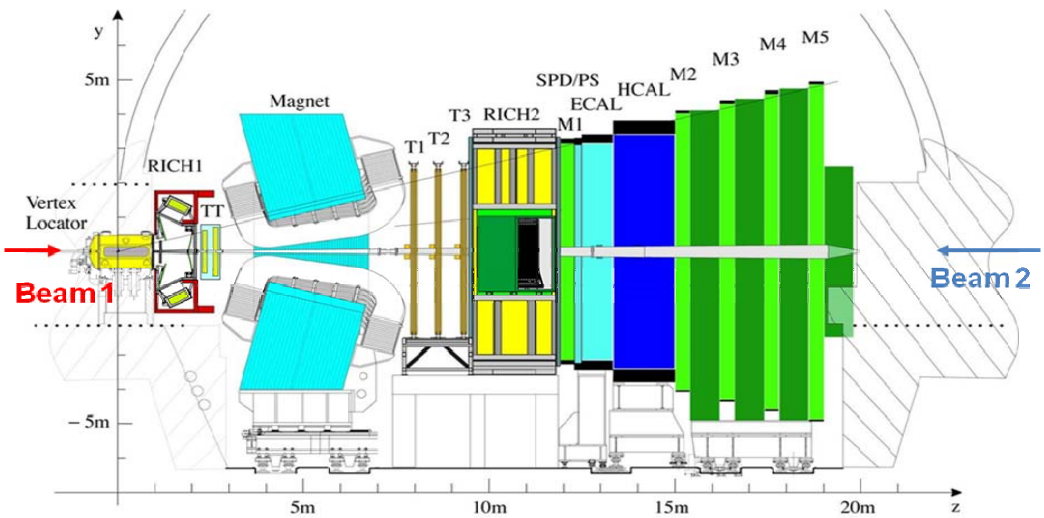

Figure 1: The LHCb detector

The acceptance is only ±200 mrad around the horizontal. The rate of such cosmics tracks in a 100 m underground cavern is well below 1 Hz. But cosmics are still useful. Close to vertical tracks can cross more than one detector, and allow time correlating them. The standard L0 hardware trigger can detect them, with an appropriate increase in the gain of the calorimeters. The muon trigger can also be modified to just become a coincidence between stations, without the pointing constraint. The L0 trigger was then commissioned with cosmics by the end of 2007, and used regularly during the whole spring and summer.

3.1 Cosmics in the calorimeter

With the increased gain, and taking into account an unexpected noise in the Cockcroft-Walton bases of the photomultipliers, the OR of the 6000 cells is counting too much. But with a coincidence between the two calorimeters ECAL and HCAL, the noise is killed completely and the rate is of the order of 10 Hz. This of course requires timing-aligning ECAL and HCAL to get this coincidence, but as this is the same electronics with the same cable lengths, this was quite easy. With that trigger, nice events (see Figure 2) were observed and used to do the fine time alignment between cells, to map dead or bad cells, and then understand and fix the problems.

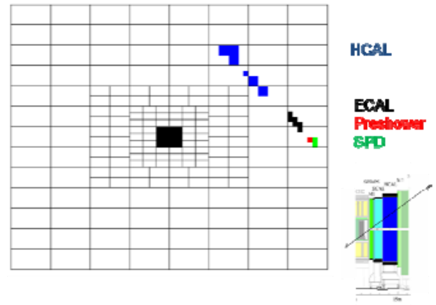

Figure 2: Cosmics event in the Calorimeter

Using the readout of consecutive crossings, the time of each event can be accurately measured by comparing the signal in the various time slices and using the pulse shape measured on test beam. A resolution of 3 ns was obtained on an event by event basis.

3.2 Cosmics with the Muon detector

The normal L0 trigger requires a track pointing to the vertex region, defined by the AND of the 4 stations. But by changing configuration parameters it can become a simple coincidence between M4 and M5 without too much pointing constraint. Many events fire both calorimeter and muon trigger, allowing to time align these triggers, and then their readout. One sees clearly on Figure 3 the difference in time for tracks going forward (from the vertex to the muon detector, normal direction) and backward (on the left). The detector is of course aligned to see the forward tracks.

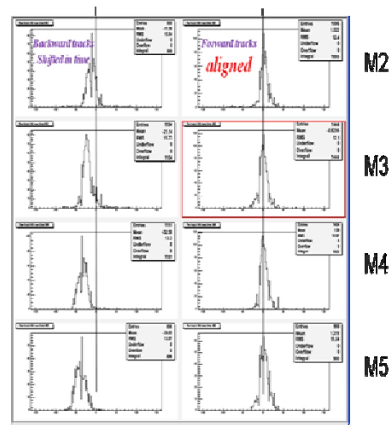

Figure 3: Time spectrum in the muon chambers

Cosmic tracks were also seen in other detectors, mainly the Outer Tracker with its large chambers. But this is almost desperate for the other detectors, too small or too far from the calorimeter where the trigger should take place.

4. First beam: TED events

LHCb is near the beam 2 injection line. In this line, there is a beam stopper (TED) at about 300 m from LHCb. Muons produced there arrive in LHCb in the wrong direction, and are mainly concentrated in the upper left corner as the transfer line is not parallel to the beam line.

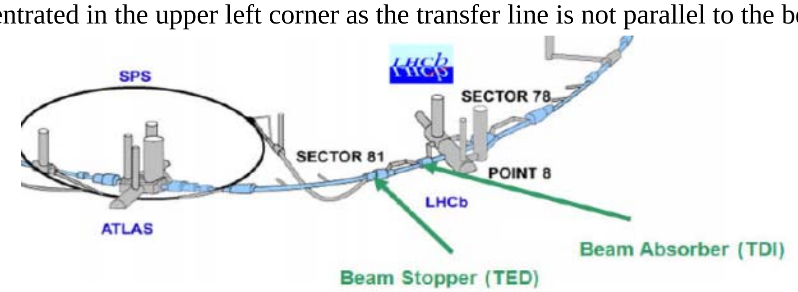

Figure 4: LHC layout showing the TED and TDI absorbers

Just after the injection kicker there is also an absorber (TDI) at about 50 m and in almost direct view. For the same beam intensity we get 100 times more particles in the detector.

The first TED events were recorded on August 22, 2008. They have a very large occupancy: typically more than 4000 of the 6000 cells of the calorimeter are fired while the trigger requires only 10 of them to have fired! The track multiplicity is certainly an order of magnitude higher, and makes track reconstruction hopeless, except for the Velo which is small enough, and not on the main core of the TED particles. A few very nice events were recorded like this one:

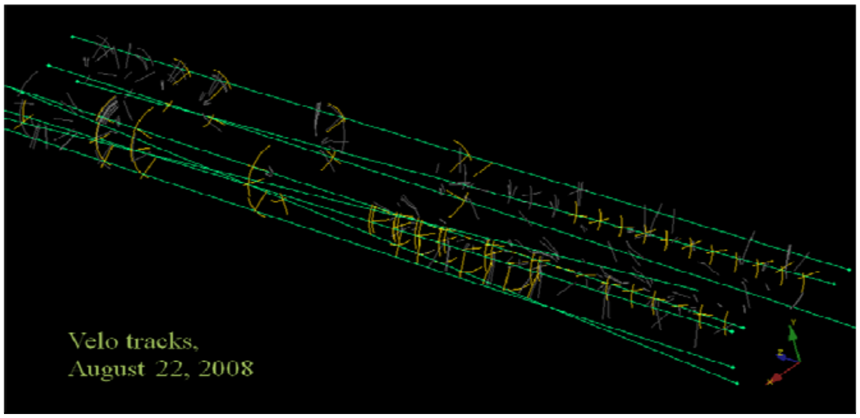

Figure 5: Typical TED event in the Velo

These few hundred events (the repetition rate was one shot every 48 seconds...) were very useful to time align the Velo with the calorimeter, and to perform a first Velo internal position alignment study: The misalignments were found to be less than 20 micrometers, as expected from metrology.

Delay scans were also performed for IT and TT (see Figure 6), measuring the average ionisation and changing the delay by steps of 5 ns. Space alignment was also looked at, extrapolating Velo tracks to the detector. A clear peak is seen on Figure 7. However, the very high occupancy made this study difficult.

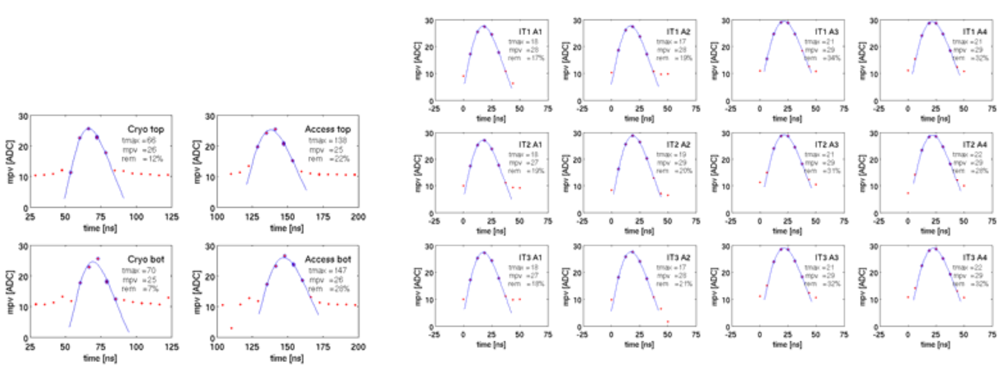

Figure 6: Delay scan with TED data for the TT (left) and IT (right)

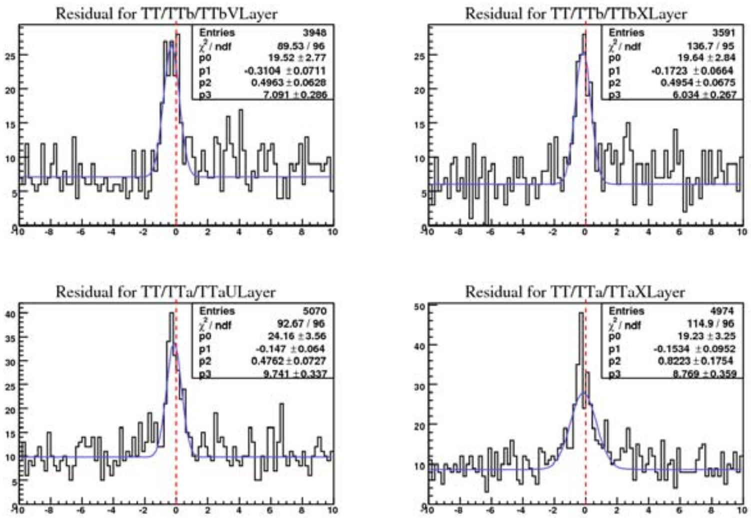

Figure 7: Residual in TT for extrapolated Velo tracks

5. With beam

As LHCb is looking only in one direction, beam 2 induced particles travel in the wrong direction. As the injection is very close, and creates a lot of particles traversing the detector, we can't use it. Beam 1 is what we want, it comes from far and injection 'dirt' is cleaned in the 20 km between the injection and us. But we got beam1 only during the 'media day', first shooting in a closed collimator in front of us, and then passing through for a single turn, and for a total of half an hour... We saw clean events, maybe beam-gas but most probably some halo interacting in the material near the detector. We had also many 'splashy' events, which extremely high occupancy.

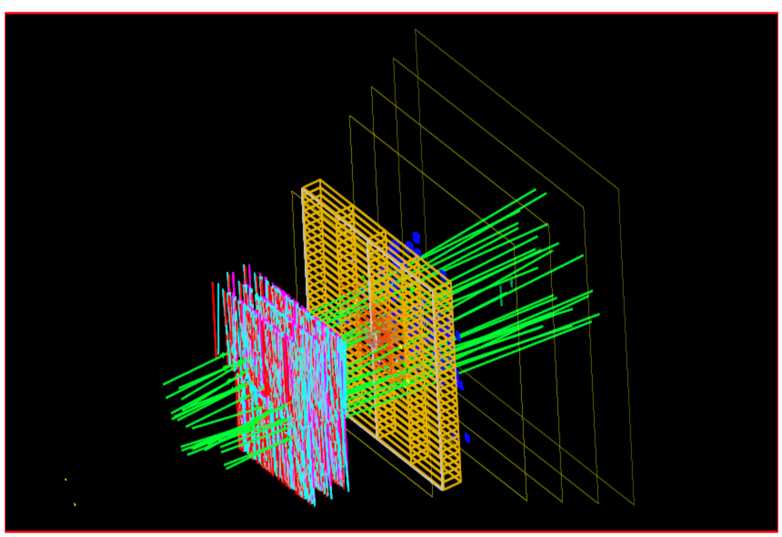

Figure 8: Example of a "splashy" event from beam 1

This permitted to see the time alignment of the OT with only 6 events, and to see light in the RICH, even if no clear ring was found: Particles are too numerous, and are not coming from the vertex area. Figure 9 shows this OT time distribution on 6 events and the HPD hits of one side of RICH2 for 30 events.

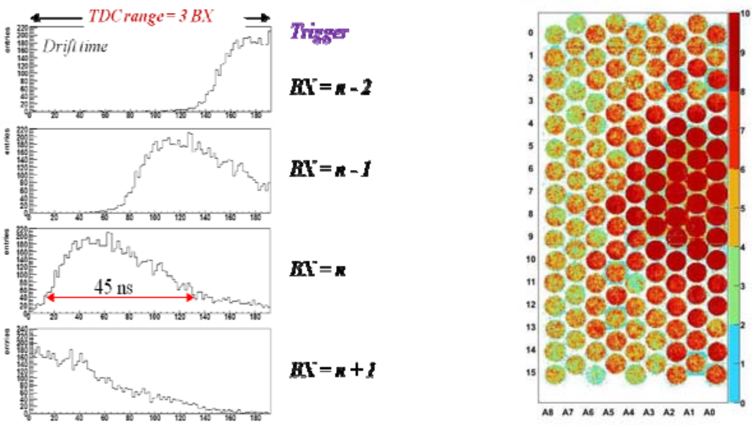

Figure 9: OT drift spectra (left) and HPD hit map (right) with beam1 of collimator

5.1 And now.

We were ready to learn more about our detector, its features and defects to be fixed during the next shutdown. We were ready to work on time and position alignment, but the dream ended abruptly and we are back to cosmics and Monte-Carlo. However many things were learned, and give work for the long shutdown, to be more ready next year,

6. Other aspects

Another important series of sub-systems were tested: The beam and radiation monitors were readout, connected to the LHC interlock system, and even fired when the beam was badly sent to a partially opened collimator! The data monitoring was also commissioned, allowing real time event display and histogram presentation using an LHCb developed tool based on Root. The online system was also performing correctly, with 50 controls PC and 200 computing farm nodes. Last, but not least, enough celebration and drinks kept the team spirit high, and the collaboration enthusiast.

7.Summary

LHCb has become an experiment, not only a collection of projects. We started to learn from each other and to share expertise and solutions. We were ready in time for the first beams, thanks to the use of cosmics for preparing the trigger and time-aligning the first few detectors. The first TED events gave the first tracks, used intensively by the tracking systems for time and space alignment, and no bad surprise was found. We are now back to Monte-Carlo studies, fixing problems, and preparing for the real machine commissioning in 2009.