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LHCb commissioning

F. Dettori(*)
Università di Cagliari and INFN, Sezione di Cagliari
S. P. Monserrato Sestu Km 0.700, 09042 Monserrato (CA), Italy

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Summary. — LHCb is a dedicated experiment for the study of b-hadrons, exploiting the copious production of beauty mesons and baryons in proton-proton collisions at the CERN LHC. The LHCb detector was already able to take data in September 2008 and now is being commissioned for the new LHC start-up in September 2009. Cosmic rays and single beam interactions data are in use for a study of the detectors performances and for their space and time alignment. Improvements in each subdetector are being performed; moreover the last of the muon stations is being installed. Full experiment system tests have shown the readiness of LHCb from the data taking to their processing. Here the current status of the LHCb experiment commissioning is presented.

PACS 29.40.-n – Radiation detectors.
PACS 13.25.Hw – Hadronic decays of bottom mesons.
PACS 13.20.He – Leptonic, semileptonic, and radiative decays of bottom mesons.

1. – Introduction

Dedicated to the study of the b-flavour quark sector, the LHCb experiment will take data in proton-proton collisions at the CERN LHC. At an energy in the centre of mass of 14 TeV, the cross-section for $b\bar{b}$ pair production is $500\,\mathrm{pb}^{-1}$, so that, with a nominal luminosity of $2 \cdot 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, 10^{12} $b\bar{b}$ pairs will be produced in one year (10^7 s) of data taking. Within this frame the CP violation and rare decays will be studied and CKM matrix tests will be performed on the full b-hadrons spectrum as well as in the *charm* sector in search for hints of new physics [1, 2].

2. – Detector overview

The LHCb detector is a single-arm spectrometer placed in the forward region of the p-p interaction point. With an angular coverage, with respect to the beam-axis, from 10

(*) On behalf of the LHCb Collaboration. E-mail: francesco.dettori@ca.infn.it

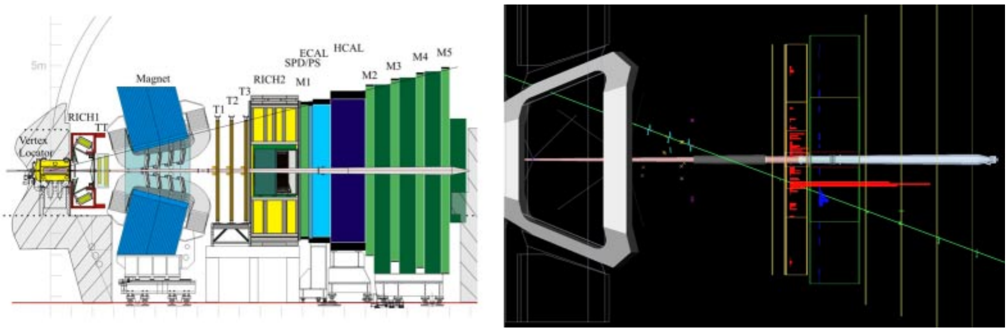

Fig. 1. – Left: layout of the LHCb detector, side view. Right: event display of one cosmic ray event as seen by LHCb detector (top view). Hits in the Tracking stations, ECAL, HCAL and Muon stations can be seen.

(15) to 300 (250) mrad in the bending (non-bending) plane, it has an acceptance from 1.9 to 4.9 in rapidity, suited to collect the $b\bar{b}$ production which, at the LHC energies, is well peaked and correlated in the forward and backward region. Here, just a brief description of the LHCb detector is given, more details can be found in [3].

The LHCb detector is subdivided in several subdetectors, a simple layout is shown in fig. 1. Around the interaction point is the Vertex Locator, a silicon detector that measures the radial and angular positions of charged tracks. The momentum measurement is ensured by the dipole magnet (integrated field of 4 Tm) and the tracking system. This last is subdivided in a Trigger Tracker (TT), a silicon micro-strips detector, and three tracking stations (T1-T3) made up of micro-strips for the inner part and straw tubes for the outer part. Particle identification, and in particular $\pi - K$ separation, is ensured by two Ring Imaging Cherenckov detectors, RICH1 and RICH2. Identification of muons is given by the MUON system, composed by one detector station (M1) placed upstream of the calorimeter system and 4 downstream (M1-M5); the stations are built up of MWPC's with the exception of the very inner part of M1 where triple-GEM detectors are exploited. Finally, energy measurement is made by the calorimeter system: a Scintillator Pad Detector (SPD) and Pre-Shower (PS), the shashlik Electromagnetic Calorimeter (ECAL) and a hadronic calorimeter (HCAL) with Fe and scintillator tiles. A summary of the expected performances of LHCb is shown in table I.

A fundamental feature of LHCb is its trigger system. The rate reduction from 40 MHz, LHC bunch crossing frequency, to 2 kHz, at which events are written on tape for later analysis, is done by two trigger levels. The Level 0 trigger is hardware based, built up of custom made electronics, and reduces the rate from 40 to 1 MHz mainly requiring particles with high transverse momentum in the calorimeters and muon system. The High Level Trigger will exploit the full event data from the detector to select events at 2 kHz. It is software based and its algorithms will evolve with the knowledge of the apparatus performance leading to high flexibility.

3. – LHCb commissioning

The commissioning of LHCb started in 2007 with tests of each of the subdetectors separately. Safety systems and hardware control and monitoring were initially tested.

TABLE I. – *Résumé of the LHCb detector performances.*

Description	Performance
Momentum resolution	$\sigma(p)/p \sim 0.4\%$
Energy resolution (ECAL)	$\sigma_E/E \simeq 9\%/\sqrt{E} \oplus 0.8\%$
Energy resolution (HCAL)	$\sigma_E/E \simeq 69\%/\sqrt{E} \oplus 9\%$
b-hadrons mass resolution	$\sigma(M) \sim 14\,\text{MeV}/c^2$
Primary [secondary] vertex position	$\sigma(\vec{x}\,) \sim 50[150]\,\mu\text{m}$
Impact parameter	$\sigma(IP) \simeq 14 + 35/p_T(\text{GeV}/c)\,\mu\text{m}$
Time resolution on b-hadrons proper lifetime	$\sigma(t) \sim 40\,\text{fs}$
Kaon identification	$\varepsilon(K) \sim 95\%$ at 5% of π/K mis-id.
Muon identification	$\varepsilon(\mu) \sim 94\%$ at 3% of $\pi, K/\mu$ mis-id.

Then hardware checks were performed including power cables (high and low voltage), signal and trigger cables; exploiting calibration pulses, mapping and connectivity were tested in order to identify dead or noisy detector channels and a first time alignment was done on the subdetectors. After this first step the LHCb detector was commissioned as a whole to be ready to take data for the foreseen LHC start date of September 2008. The system control, which exploits PVSS SCADA to control processes and Finite State Machines for state and commands, was already taken from one console by a small shift crew. The detector readout was commissioned at 100 kHz limited by the network and event filter farm and a data storage at 2 kHz was already exploited.

3·1. *Commissioning with cosmic rays events*. – The LHCb detector is not well suited for the detection of cosmic rays, which arrive mainly in vertical direction; nevertheless, even if at low rate (less than 1 Hz), about 10^6 events have been collected and used in order to understand the detectors behaviour; one example of these events can be seen in fig. 1. Cosmic rays data have been useful for various tasks. The basic blocks of the trigger have been tested and commissioned successfully. A first spatial alignment and coarse time synchronisation have been executed on bigger subdetectors. In particular for the MUON system, after data analysis and correction for the muons time of flight, the detectors time resolution has been measured and found to be 5(6) ns for M2, M3 (M4, M5) stations (laboratory measurements gave 5.7 ns with these conditions).

3·2. *Commissioning with beam induced events*. – During summer 2008 beam injection tests were performed. The beam was dumped on a beam-stopper (TED) 300 m behind LHCb and 8 (12) mrad horizontally (vertically) displaced from the LHCb beam axis. A high particle density was produced in these dumps ($10/\text{cm}^2$ of particle flux on the beam dump axis, $0.1/\text{cm}^2$ on the VELO) and detected by LHCb. Even if TED particles came from the *wrong* direction (*i.e.* MUON first) and were not centred, the produced tracks helped in aligning the detectors, especially the smaller ones, in space and time. In particular in fig. 2 is shown an example of the distribution of the difference of VELO alignment constants obtained with two different data samples. The computed resolution is $5\,\mu$m for x or y translations and $200\,\mu$rad for z rotations. Tracks on the VELO have been extrapolated in to the TT and matched to hits in the latter; computed hits residuals distribution for one sector of the detector is shown in fig. 2; the average resolution is $500\,\mu$m

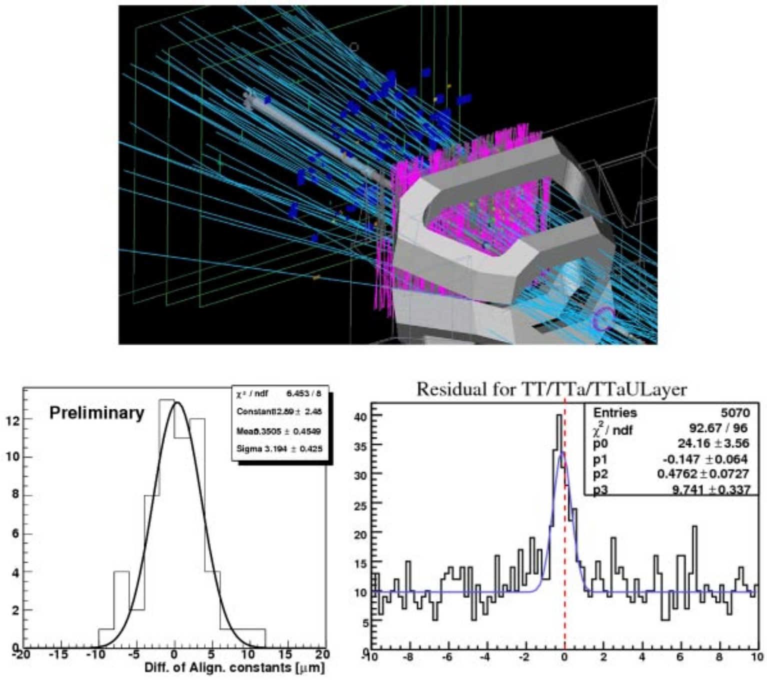

Fig. 2. – Top: event display of a beam interaction with the collimator as seen by the LHCb detector. Left: example of VELO alignment constants difference distribution from two different data samples. Right: example of the distribution of TT hit position minus the extrapolations from tracks in the VELO.

and the offset is 150–300 μm compatible with the expected extrapolation uncertainty of $\sim 300\,\mu$m.

On September 10th 2008 new beam tests were performed, with the beam injected upstream the LHCb detector and circulating, for about 30 minutes, in the *right* direction for LHCb (*i.e.* VELO first). Many clean beam-gas interaction events and some *splash* events, with beam hitting the collimator, were recorded; one of these events can be seen in fig. 2. During these tests control and DAQ systems showed a very good response and the consecutive trigger reading was exploited.

3˙3. *2009 shutdown activities*. – During the LHC shutdown (after a fault was discovered in LHC on September 19th) the activity moved to the commissioning of LHCb for the new start. First of all, the installation and commissioning of last Muon Station (M1), which was not installed before for time reasons, is in progress. In May 2009 more than half of the chambers are already installed and tested. Improvement and repairs plus standard maintenance have been performed on each of the subdetectors. The full-size readout network for 1 MHz readout has been installed and commissioned with the installation of 350 more online farm computing nodes (the total now is 550 and infrastructure is ready for 2000 nodes). Full Experiment System Tests (FEST) have been performed: these runs tested the whole data acquisition machinery at nominal rate. In particular, instead of reading the detectors, Monte Carlo generated data was injected in the readout and processing network. A rate of 1.9 kHz was achieved, limited by the Monte Carlo data injector.

4. – Conclusions

The LHCb experiment was ready to take data in 2008. Good use has been made of the cosmic rays data, despite the detector orientation, for time and space alignment. Beam-induced events helped in tuning the small detectors.

LHCb will be even more ready in 2009 thanks to the installation of the last muon station, a finer detector tuning, the installation of the full readout network and the experience gained with the FEST. Commissioning of LHCb will continue looking forward to the physics data taking run in 2009.

REFERENCES

[1] LHCb Collaboration, *A Large Hadron Collider beauty experiment*, Technical Proposal, CERN/LHCC 1998-004.

[2] LHCb Collaboration, *LHCb reoptimized detector design and performance*, Technical Design Report, CERN-LHCC-2003-030.

[3] LHCb Collaboration, *JINST*, **3** (2008) S08005.