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Commissioning of the LHCb RICH detectors

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ABSTRACT

The LHCb experiment features a particle identification system composed of two RICH detectors, flanked by a magnetic tracking configuration. This system is now being readied for data taking. The first beam is scheduled for 2008. We will discuss the commissioning strategy and point out some key issues and the approach which has been adopted to solve them.

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1. Introduction

Particle identification is a fundamental requirement of the LHCb experiment [1]. The ability to distinguish between pions and kaons in a variety of final states is essential for the physics that the experiment is designed to study. Meaningful CP-violation measurements are only possible in many important channels if hadron identification is available. The particle identification system is composed by two RICH detectors [2], flanked by a magnetic tracking system and the associated calorimeters and muon detectors. The RICH detectors covers the full angular acceptance of the spectrometer, from 10 to 300 mrad in the horizontal projection, the bending plan, and to 250 mrad in the vertical projection. There is a strong correlation between the polar angle and the momentum of the tracks from two-body B-decays. The momentum spectrum is softer at wide angles. Thus, two active media and a very close position to the interaction point ensure wide angular and low to medium momentum coverage for RICH 1. RICH 2 is placed after the tracking system and is designed to give positive kaon identification up to 100 GeV/c. Its coverage is limited to the region 120 mrad (horizontal) $\times$100 mrad (vertical), where high momentum tracks are abundant. The two RICH detectors are built around the same model. A system of spherical and flat mirrors focuses the Cherenkov photons onto the photon detectors which are made up from a total of 484 HPDs [3]. The silicon pixel detector of each HPD has 2^{13} elements which can be read out in two modes, either as single elements, ALICE mode, or as groups of eight actively OR-ed elements, LHCb mode. The latter gives a resolution on the photo cathode of about $2.5 \times 2.5\,\text{mm}^2$. Data readout and logging is performed at a sustained average 1 MHz rate, reduced from 40 MHz by a zero trigger level.

Development and design of components, followed by their installation and integration in the LHCb system has taken about 10 years and the RICHes are now being commissioned for physics data taking in 2008. Being innovative in many aspects of hardware as well as middleware, software and physics analysis tools, a strategy for their commissioning had to be developed. This has included safety for people and components with an emphasis on effectiveness, reliability together with overall compatibility with the general commissioning of other LHCb components and at the same time keeping cost and time scale within the guidelines.

We will here describe pre-, local- and global commissioning of our RICH detectors. We will point out major steps and challenges towards the operation-ready state, together with a summarized description of the control, calibration and acquisition sub-systems involved. First results from the commissioned system will be shown, described and detailed, in view of easy, consistent and smooth start of LHCb physics runs.

2. Commissioning strategy

Commissioning is to assemble all elements of the detector, from hardware to offline analysis tools, to one coherent entity ready to take data and, from there, produce physics results. Every single component has previously been tested and evaluated separately or together with a few other modules. The task of the commissioning is then to analyse each component and incorporate them into one entity and at the final stage, merge this into the experiment. The first condition for a successful detector commissioning is to ensure safety for the equipment and people working on it, from human errors and hardware failures. The second condition is to achieve as much as possible in laboratories and at test beams rather than underground at the experimental zone. Therefore, whenever possible, a number of prototypes and test-benches have been produced by the collaboration, in order to test

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and characterize the detector sub-systems. These are summarized in: the mechanical system [4], the optical system [5], the photon detector system [6], the experiment control system (ECS [7]), the detector safety system (DSS [8]) and the data acquisition system (DAQ [9]).

At the onset of the commissioning exercise, alarms, interlocks and intelligent reaction components have been implemented and activated on the detector to make use of the experience accumulated with prototypes and test-benches. In particular, the ECS, which is being developed in common within the Joint COntrols Project (JCOP [10]) is managing the configuration, control, monitoring and data archiving of all the components of the online system. In the RICH this includes: control and monitoring of the high/low voltage power supplies, monitoring of important values of temperature, pressure and light intensity, interaction with peripheral equipment as well as data acquisition, trigger and timing. Although the major part of electronics cooling and gas systems is not a direct responsibility of the experiment, we have kept in close contact with the groups responsible. For further details, the reader is referred to Ref. [11].

3. RICH 1 and RICH 2 commissioning

For RICH 1 and 2, the respective optical systems were built, integrated and aligned in the laboratory at CERN. Specific optical benches were used to test mechanical precision and reliability of the mirror supports and to align to high precision the mirror arrays [4]. For RICH 2 the optical system was integrated in the vessel at the surface and then carefully transported to the pit [11].

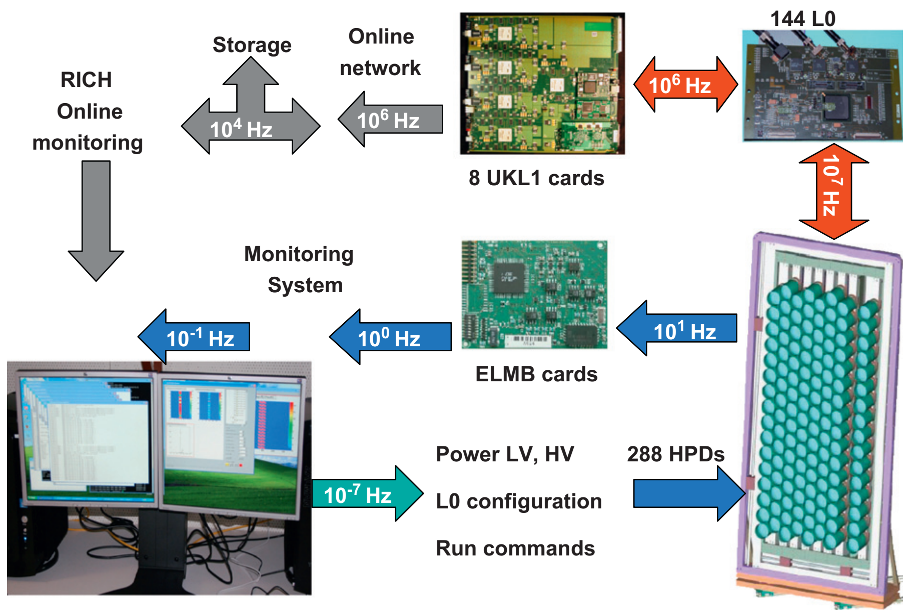

Fig. 1. Schematic representation of data flow together with control and monitoring signals for the RICH detectors.

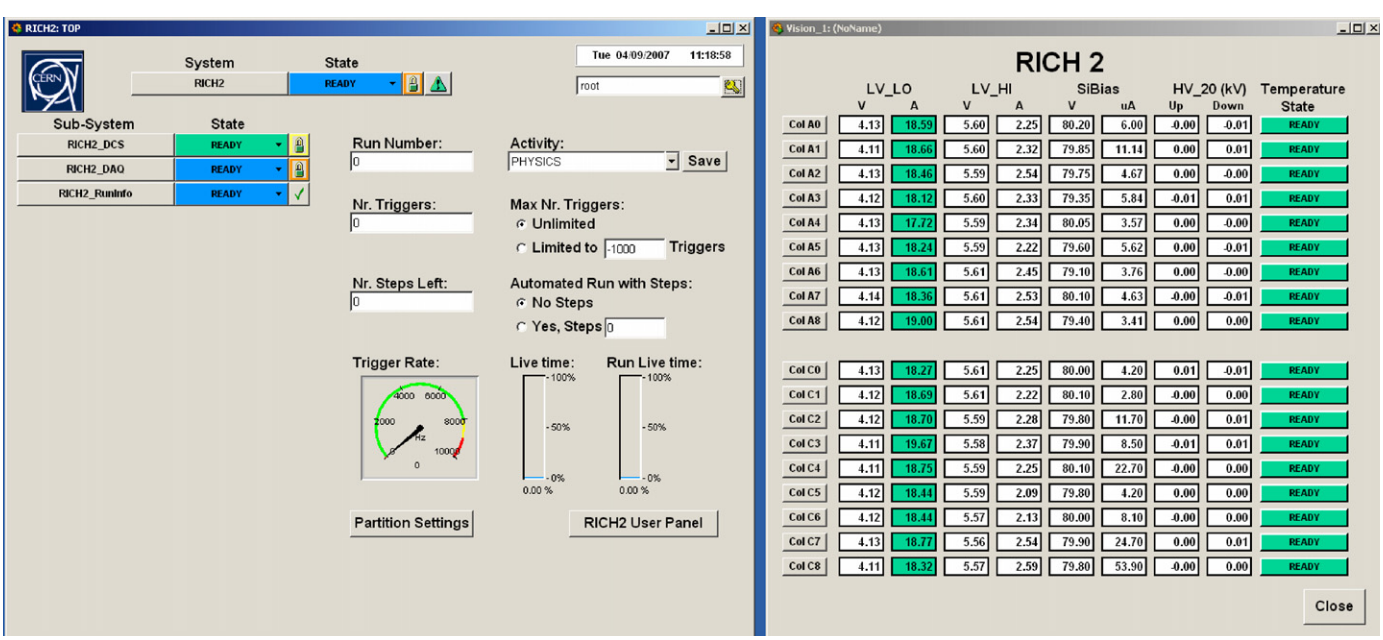

Fig. 2. Control and monitoring panels for RICH 2. The most important run parameters are given in the right hand panel. The ECS panel is shown on the left side. From here the operator can with a "*One Click*" prepare, start and terminate a run.

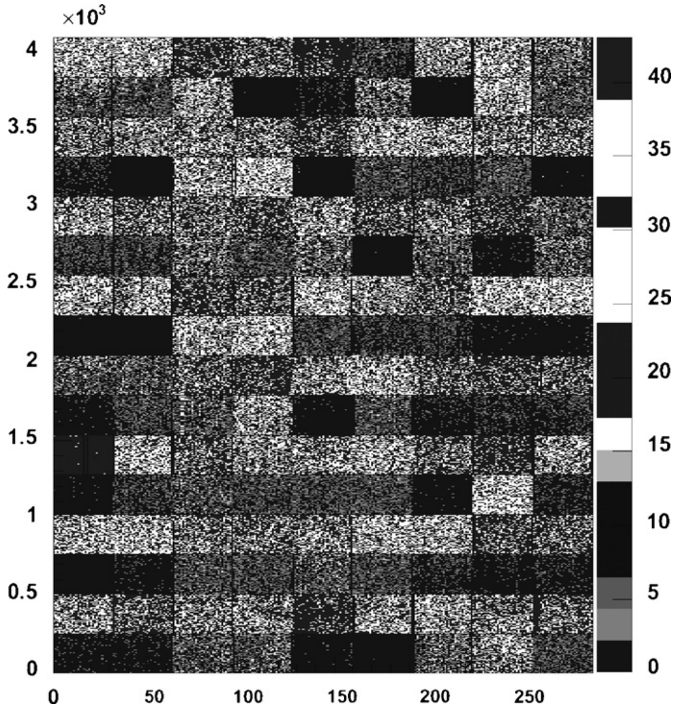

Fig. 3. Monitoring scatter plot of one side of RICH 2 for random triggers. Each square represents one HPD, 8192 pixels. A total of about 1.2 M signal channels are plotted.

For RICH 1 the aligned optical system was integrated in its vessel at the pit [12].

RICH 1 and 2 share the same electronics chain all the way through, apart from some minor mechanical differences [13]. Two benches were set up in order to thoroughly test RICH columns made of several HPDs each and instrumented with low, high and Si bias voltage supplies and On Detector electronics boards, L0, to send the proper signals to the DAQ system. The first bench is devoted to test column electrical integrity and HPD functionalities and it was prepared to be used as a vessel for several test beam experiments [14]. The second bench was set identical to the final system, yet with only one column containing 16 HPDs. It was complete with the final electric and electronic hardware and with control computers, DAQ lines, and network and data processors all the way up to the storage system (Fig. 1). It was the test bench to develop and run all control, monitoring and acquisition software to be installed afterwards at the experimental site. These benches were also used to test prototypes for our timing, magnetic distortion and alignment systems [15].

When all hardware and software were developed, tested and ready, the commissioning activity was moved to the experimental site. The commissioning of RICH 2 has been relatively straightforward. Signals from the front-end of the HPD chips [16,17] were properly acquired through the complete DAQ and online chain just a few days after the completed integration and software installation.

RICH 2 was fully controlled by ECS. Monitoring was active and emergencies could be handled by an optimized alarm-error system [18] (Fig. 2). From a simple computer console, the operator

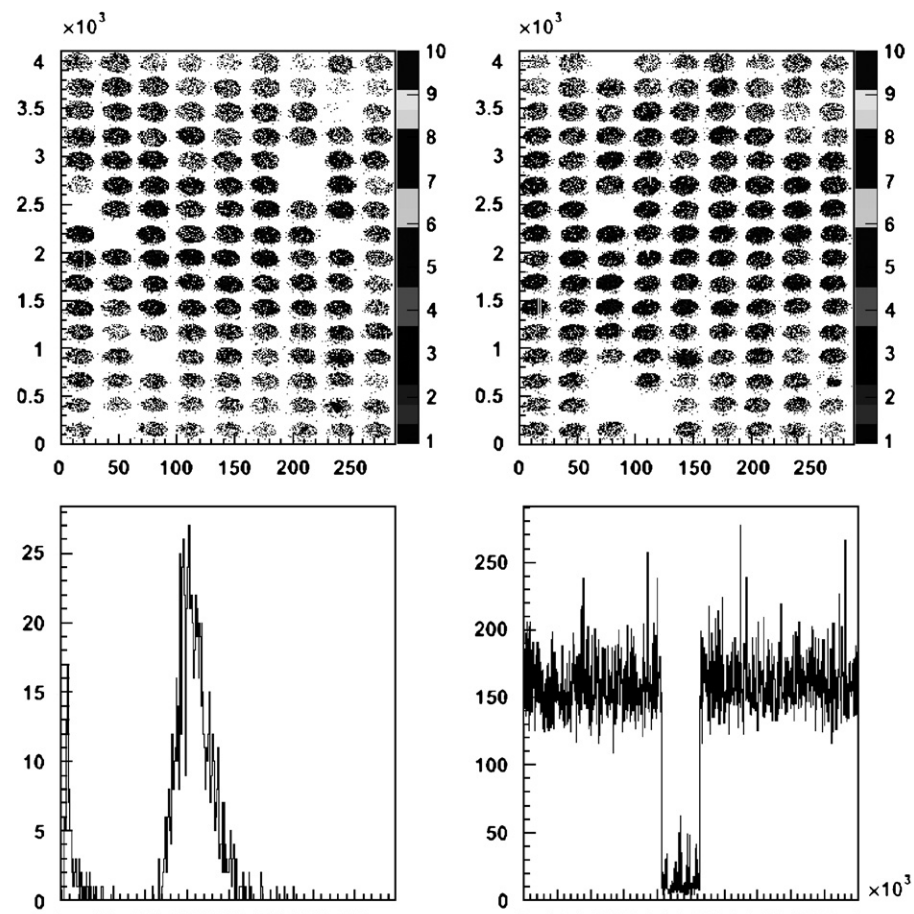

Fig. 4. RICH 2 time alignment. All HPDs, apart from a few disabled, were operated at 20 kV. The top two plots show accumulated scatter plots for the two sides. The bottom left plot show the distribution of the total number of detected photo electrons and, bottom right, the number of photo electrons for each trigger.

can set-up RICH 2, start an acquisition run and decide if, where and how to store the data. On the same console, the operator can check that normal conditions are well enforced by the online monitoring system. It will provide a complete set of one- and two-dimensional histograms [19] (Fig. 3).

Special care was taken in commissioning the high voltage system for the HPDs [18]. In order to reach safely and smoothly the operational 20 kV, the HV was raised very slowly, about 10 V/s, and kept at set voltages for some time. Meanwhile the whole RICH 2 was switched on and data from the HPDs were taken and monitored online. This allowed us to safely ramp up and to find possible critical issues well in time before getting to 20 kV.

Time alignment scans have been done by shining light from a laser source with sub-ns time resolution onto the photon detectors of RICH 2 (Fig. 4). In this way each HPD is synchronized within a few ns to the main LHCb trigger system [13]. The depletion in the bottom right plot, Fig. 4, shows the difference between On-Time and Out-of-Time.

4. Conclusions

The successive months are being dedicated to implement and to improve RICH 2 calibrations, stability, reliability, robustness and to exercise HPDs and keep them powered and under high voltage. The time will also be used to gain experience and confidence in addition to acquire useful data and to prepare for the particle beams [15,20].

At present the commissioning of RICH 1 is starting. As all the opto-electronics chain, control and monitoring systems are virtually identical to those of RICH 2, we expect a smooth and speedy commissioning phase. The detectors will be ready and fully tested when the first beams will be injected in the summer of 2008.

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